THE

PROCEEDINGS AND TRANSACTIONS

OF THE

Nova Scotian Institute of Science

HALIFAX, NOVA SCOTIA.

VOLUME XIII

PART 4

SESSION OF 1913-1914

HALIFAX
PRINTED FOR THE INSTITUTE BY THE ROYAL PRINT AND LITHO, LIMITED
Date of Publication: 24th July, 1915.

PRICE TO NON-MEMBERS: ONE HALF-DOLLAR

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THE attention of members of the Institute is directed to the following recommendations of the British Association Committee on Zoological Bibliography and Publications:—

"That authors' separate copies should not be distributed privately before the paper has been published in the regular manner.

"That it is desirable to express the subject of one's paper in its title, while keeping the title as concise as possible.

"That new species should be properly diagnosed and figured when possible.

"That new names should not be proposed in irrelevant footnotes, or anonymous paragraphs.

"That references to previous publications should be made fully and correctly, if possible in accordance with one of the recognized sets of rules of quotations, such as that recently adopted by the French Zoological Society."

PROCEEDINGS

OF THE

Nova Scotian Institute of Science,

SESSION OF 1913-1914.

ANNUAL BUSINESS MEETING.

Civil Engineering Lecture Room, Technical College, Halifax; 8th October, 1913.

THE PRESIDENT, DONALD M. FERGUSSON, in the chair.

Others members present: Dr. A. H. MacKay, Dr. H. L. Bronson, Maynard Bowman, Dr. E. Mackay, Alexander McKay, Dr. D. Fraser Harris, Donald S. McIntosh, Carleton B. Nickerson, W. McKerron, J. H. L. Johnstone, and Harry Piers.

PRESIDENTIAL ADDRESS: (1) Deceased Members; (2) Problems in Biochemistry.–By DONALD M. FERGUSSON, F.C.S., Halifax.

I take this opportunity of thanking the members of this Society for the honor conferred in electing me as President, an honor the more appreciated as during this term we have reached our jubilee as a society.

Deceased Members.

During the past year we suffered the loss of two members who have passed from this life.

GEORGE UPHAM HAY, Ph. B., M. A., D. Sc., F. R. S. C., corresponding member of this society, was born at Norton, N. B., June 18th, 1843. Starting as a journalist he became an educationist and was a power for advancement in our sister province. With Dr. A. H. MacKay, he established the *Educational Review*, which he managed and edited; and latterly he published several historical works. It was as a botanist that we knew him. He was a president of the Natural History Society, St. John, president of the Botanical Club of Canada, and member of the New England Botanical Club. In 1904 he was president of Section IV of the Royal Society of Canada. In 1902 he was elected a corresponding member of this Institute. His contributions to botany were many and varied and are found in the Transactions of the Royal Society of Canada, Bulletin of the Natural History Society, N. B., and Educational Review. He also contributed papers on education and natural science to the Proceedings of the Dominion Education Association, Educational Institute of N. B., and Educational Review.

JAMES GORDON MACGREGOR, M. A., D. Sc., LL. D., F. R. S., F. R. S. C., F. R. S. E., was a native of Halifax, N. S., being born March 31st, 1852. Educated here he obtained his B. A. at Dalhousie University in 1871 and M. A. in 1874. From hence he proceeded to Edinburgh University and to Leipzic and obtained the D. Sc. degree from London University in 1876. In the same year he became lecturer on physics at Dalhousie, changing to a like position at Clifton College, England, a year later. Coming back to Dalhousie University to take the Munro professorship of physics in 1879, he remained there until 1901 when he left to become professor of natural philosophy in Edinburgh University, succeeding his

old teacher Prof. P. G. Tait, and occupying that post until his death.

As a student at Dalhousie University he had a career unsurpassed in the history of that institution, the calendar of 1871 showing his name opposite every prize open to him, and his subsequent life was but a continuance of that appetite and capactiy for work which distinguished his early days.

While holding the position of Munro Professor of Physics at Dalhousie, he for several summers during his vacations, returned to Edinburgh to work in the larger laboratories there, and thus when Edinburgh University called him, he was no stranger, but one whose worth and value were known.

At Dalhousie University he acted as Secretary of the Faculty of Arts, and later as Secretary to the Senate, and there as in his laboratory and class rooms he was a source of inspiration to those with whom he came in contact. The same may be said of him in relation to our society which he joined in January, 1887. He was our President 1888-91, and for the work he did in this connection I must refer you to the paper on Past Presidents given at the beginning of this last session by our able Secretary, Mr. Piers.

At Edinburgh, he, during the twelve years there, developed and extended the Department of Natural Philosophy, changing the old Infirmary in Drummond Street into a well equipped physical laboratory, and his energies in that direction were only limited by lack of funds.

A foundation F. R. S. C., he was President of the mathematical and physical section of that body in 1892, was a Fellow and Councillor of the Royal Society of Edinburgh, and in 1900 was elected a F. R. S.

He contributed papers to our Society, to the Trans. Roy. Soc'y, Canada, Philosophical Magazine and the Physical Review, and was author of "Kinematics and Dynamics" (1887-1902) and "Physical Laws and Observations."

Taken suddenly ill on the morning of May 21st, 1913, he had time to call his son and died almost immediately afterwards. We deeply feel his loss, for to many of us he was a true friend. A man of unselfsh character and lovable, he devoted himself entirely to those around him, to his students, his fellow scientists and his family. Cognizant of our own loss, we can extend our sympathies to those bound by family ties, whose loss is not only that of the man but of husband and father.

Biological Chemistry.

The chief event, this session, in our society, has been the passing of the fiftieth milestone, and although a review would naturally suggest itself, yet any fair summary of our work would exceed the usual limit of the annual address. I have chosen rather to speak of a branch of chemistry that is now beginning, or rather has well begun, and that bids fair to be foremost in the field during the next half century.

Fifty years ago in 1863 Duvaine first established a connection between bacteria and disease, identifying a bacillus as the cause of anthrax. Down through the years intervening has research continued; bacteriology has grown to be one of the most important of the biological sciences, and one whose applications have immensely benefited humanity. One by one the bacteria, pathogenic and nonpathogenic, were isolated, and there followed methods of growing, staining and identification. From inoculations of filtrates from culture growths of pathogenic bacteria, physiological disturbances identical with those in the disease were observed. Immunity in varying degree had been known as a result of disease, and it was found that immunity could be obtained by inoculation of the artificial growth filtrate. Thus arrived the ideas of toxins and antitoxins which form the basis of the modern immunity theory.

Other bodies formed by bacterial infection were noted, such as lysins and agglutinins, the formation of the latter

being taken advantage of in the Widal test for typhoid infection. A vast amount of work was done on the effect of introducing into the blood stream foreign elements such as blood corpuscles of other species, albuminous bodies, e.g., serums, extract of muscle, etc. These developed antibodies, and we have now the biological blood test, precipitin test for flesh, and many others. Here we have evidence of a large number of reactions — chemical reactions—between bodies of whose composition and properties little is known. To investigate such is the work of a new individual, the biological chemist. There lies open to him a new and immense field in the chemistry and physics of life, in the science of the cell, with its protoplasmic contents and their activities.

The biochemist is a new specialist who must have a long and varied training, for so co-related are the sciences that he who would interpret aright the phenomena he observes must have the broadest foundation on which to build.

With some point of kinship to the toxins we have as cell products the Enzymes. The enzmyes of digestion and fermentation have long been known and investigated, and a host of enzymes are classed as catalysers, and much work has been done on the dynamics of reaction and the effect of activating and inhibiting agents.

Being catalysers, accelerators of reaction, they need only be, and are, present in small quantities, but they have a most important part in synthesis and degradation of organic matter in the life cycle. Up to the present it cannot be said that any enzyme has been obtained in a state of purity. Methods of purification employed destroy activity for some reason or other, so that little is known of their constitution beyond a general analysis.

Work is being done on the physics of the cell, on surface tension, osmotic pressure, etc. About two years ago Prof. MacCallum by means of a microchemical stain was able under the microscope to show the distribution of Potassium in cells,

and connecting the distribution of electrolyte with surface tension gave an explanation of muscle contraction and the associated nerve impulse. He also showed that a concentration of electrolyte, or ions, at one point in the living cell would explain why is was that cellular membranes acted differently in the organism from the way in which they act as dead membranes in the laboratory during osmotic experiments.

Last year Czapek published results on higher plant cells, which have a bearing on secretion and excretion. He found that these cells did not part with their soluble constituents in osmosis until the surrounding media had its tension lowered to .65 (water air surface-1). Red blood corpuscles and yeast cells did not give up haemoglobins and invertase respectively until the surface tension was reduced to .5.

One line of biological research that is going on at the present time, one on which much time and money has been spent, and the research which appeals most to the world at large, is the endeavor to find the cause and cure of cancer. The cell of abnormal growth presents a difficult biological problem. Here is a cell which breaks away from the mechanism controlling growth, and starts on a career of its own, like a semi-independent organism. Proliferating with increased rapidity it departs from its type also in division, showing varying abnormality in karyokinesis. After the physical chemistry of the normal cell is known, the abnormal cell will still present itself. Two new and important methods of technique have recently been announced which may aid in the solution of the problem. One is Dr Carrel's method of tissue growing *in vitro*, and the other is the method of *intra vitam* staining as shown by Prof. Goldmann before the Royal Society last year.

Let us hope the cure will be discovered long before the biochemist arrives at the scientific explanation of the cell of abnormal growth.

The rediscovery of Mendel's work in 1900 gave an impetus to scientific breeding experiments with animals and with plants Results of economic importance and scientific value have followed. Cambridge has given the English farmer cereals increased in strength and yield and immune to rust, hereditary qualities capable of being transmitted in accordance with Mendel's law of segregation. As the chemist now looks to the physicist for the constitution of his unit, the atom; so the biologist appeals for the exploration of his unit, the cell, to the biochemist. With the union of gametes we have the cell in which the problem of heredity is wrapped up; and as Dr. Schäfer has said, we must not be blind to the possibility that these transmitted qualities may be connected with specific chemical characters of the transmitted elements: in other words, that heredity is one of the questions the eventual solution of which we must look to the chemist to provide.

Miss Wheldale has recently done work on the coloring of flowers, finding chromogens supposedly derived from glucosides by hydrolysis, in which the color is developed by enzyme oxidases and peroxidases. White flowers may be of two kinds, one in which chromogens are absent and the other in which they are present, but unacted on by the enzymes. Prof. Keeble and Dr. Armstrong have investigated this subject and developed chemical tests to distinguish the two kinds of white flowers, to do which previously, breeding experiments would have been required. The significance of this is, that here we have the beginning of the chemists' work on heredity, color being a Mendelian unit-character.

Examination of the bacterial content of soils has shown their intimate connection with plant growth, and the parts played by some of these organisms have been worked out. Recent work on partial sterilisation of soils, after which the bacterial growth is much enlarged with consequent increase in crops suggests the destruction of protozoan enemies of the bacteria as the cause of increased bacterial content.

The term catalytic fertilizers has been applied to compounds of manganese, boron, zinc, etc., which when added to the soil in small doses have in cerain cases caused remarkable yields of crops.

The U. S. Dept. of Agriculture has given us a soil poisoning theory, finding di-hydroxystearic acid present in impoverished soils. Experiments at Rothampstead, England, have failed to confirm this. All these problems are still under investigation as are those of soil solutions, capillarity of soils, water level, etc., in relation to plant growth.

I have mentioned only a few of the subjects which the biological chemist is investigating, for the field of research is large indeed.

To show the growth of this new science, I may mention that Chemical Abstracts (published by American Chem. Society) for August 1908 contained 52 references to articles on biological chemistry whilst the August numbers for this year contained over 600 abstracts.

In the future the biochemist must simplify the language of immunity, replacing the present word-pictures by definite molecular formulae and equations. We look to him to isolate, find the composition of and eventually synthesize the enzymes, secretins, hormones, antitoxins and a host of other bodies. He must find out nature's secret when she manufactures in her laboratory by means of enzyme and chlorophyll the countless substances found in plant life, and must give us the enzyme or other catalyst to work at ordinary temperatures and utilise the sun's radiations going to waste around us. In short, he must solve the problem of photosynthesis. Ciamician, in his address before the International Congress of Applied Science last year, has given us a picture of the future, thus: "On the arid lands there will spring up industrial colonies without smoke and without smoke-stacks; forests of glass tubes will extend over the plains and glass buildings will rise every-where; inside of these will take place

the photo-chemical processes that hitherto have been the guarded secrets of the plants, but that will have been mastered by human industry which will know how to make them bear even more abundant fruit than nature, for nature is not in a hurry and mankind is."

After the physics and chemistry of the life processes are laid bare, after metabolism and its derangements are understood, then may come some idea of life and its origin. Present ideas of origin may be summed: (1) that life is originating even now around us, but beyond our powers of observation, (2) that life had its origin in finite time, and (3), the view of Arrhenius, that life had no origin in finite time but was coeval with matter and energy at infinite time. If the physicist destroy our notion of matter there will remain but life and energy; and it may be that that dualism is more apparent than real, for we only know life by energy change.

The Present Trend and Suggestions.

The solution of these problems necessitates long and continued research and that means time and money. I should like to see our provincial colleges so endowed as to give much more opportunity for research than at present. Sir J. J. Thompson, regarding students, has said: "I have always been struck by the quite remarkable improvement in judgment, independence of thought and maturity produced by a year's research. Research develops qualities that are apt to atrophy when the student is preparing for examination and quite apart from the addition of new knowledge to our store it is of the greatest importance as a means of education."

Not only could we have more research for our students but our professors should be so situated as to be able to engage in research, and not be tied down attending to all the small details of college work.

A feature of our day has been the appointment of national commissions on Conservation of National Resources. The

powers of these bodies could be vastly extended to providing endowment for research and founding establishments like the Kaiser Whilhelm Institut in Germany. If civilised nations could see the absurdity of settling ethical issues by destruction of cellular tissues, large sums of money would be available for research into conserving the national resources which we use at present, and tapping those going to waste around us. We might then feel less ashamed of what future generations will think of the manner in which we squander their birthright of mine, field and forest. We have passed our fiftieth year and some of our younger members may see the centenary of our society. Then many present researches will have been finished but we can assure ourselves that the field ahead will be more expanded than we dream of.

Tonight we have reports fromMuseum and Science Library. Fifty years after this, I hope that commensurate with the large increase of population we see looming ahead the reports will show that each of these institutions will occupy as much space as the whole of the buildings in part of which they are now housed. The growth of such institutions but reflects the vitality of that phase of intellectual development which it is our pleasure and duty as a society, to advance,and which must be carefully fostered if we in this Province would keep pace with other peoples in deriving pleasure and profit from the search into Nature's secrets.

The Treasurer, M. Bowman, presented his annual report, showing that the receipts for the year ending 31st September, 1913, were \$1,042.43; the expenditures, \$914.17; and the balance in current account, \$128.26; while the reserve fund was \$300.00, and the permanent endowment fund, \$939.49. The report was received and adopted. Attention was drawn to the desirability of raising the permanent endowment fund to one thousand dollars, and then investing it in suitable bonds. This was referred to the Council for consideration.

The Librarian's report was presented by H. PIERS, showing that 1,763 books and pamphlets had been received by the Institute through its exchange list during the year 1912; and 1,298 have been received during the first eight months of the present year (1913). The total number of books and pamphlets received by the Provincial Science Library (with which those of the Institute are incorporated) during the year 1912, was 3,385. The total number in the Science Library on 31st December, 1912, was 48,882. Of these, 35,848 (about 73 per cent.) belong to the Institute, and 13,034 to the Science Library proper. The number of books borrowed was 440, besides those consulted in the library. No binding or purchasing was done by the library, directly, during the year, there being no regular grant for the library's support. The report was received and adopted.

D. S. McINTOSH, M. Sc., instructor in geology, Dalhousie University, delegate appointed to represent the Institute, read a report on the work of the Twelfth Session of the International Geological Congress, which was held at Toronto, Canada, from 7th to 14th August, 1913, there being 950 members enrolled and 433 in attendance. The Nova Scotian excursion, 20th to 29th July, was one of the most interesting of those held. The report was received and adopted.

It was reported that HORACE GREELEY PERRY, M. A., professor of biology, Acadia University, Wolfville, N. S., had been elected an associate member on 12th May last.

The following were elected officers for the ensuing year (1913-14):

President,—DONALD MACEACHERN FERGUSSON, F. C. S., *ex officio* F. R. M. S.

First Vice-President,—PRESIDENT ARTHUR STANLEY MACKENZIE, Ph. D., F. R. S. C.

Second Vice-President,—ALEXANDER HOWARD MACKAY, LL. D., F. R. S. C.

Treasurer,—MAYNARD BOWMAN, B. A.

Corresponding Secretary,—PROFESSOR EBENEZER MACKAY, Ph. D.

Recording Secretary and Librarian,—HARRY PIERS.

Councillors without office,—PROFESSOR CLARENCE LEANDER MOORE, M. A., F. R. S. C.; ALEXANDER MCKAY, M. A.; PROFESSOR DAVID FRASER HARRIS, M. D., C. M., D. Sc., F. R. S. E.; DONALD SUTHERLAND MCINTOSH, B. A., M. Sc.; CARLETON BELL NICKERSON, M. A.; PROFESSOR HOWARD LOGAN BRONSON, Ph. D.; and WILLIAM HARROP HATTIE, M. D.

Auditors,—WATSON LENLEY BISHOP and WILLIAM MCKERRON.

FIRST ORDINARY MEETING.

Civil Engineering Lecture Room, Technical College, Halifax; 10th November, 1913.

THE PRESIDENT, D. M. FERGUSSON, in the chair.

DAVID FRASER HARRIS, M. B., C. M., M. D., D. Sc., F. R. S. E., professor of physiology and histology, Dalhousie University, Halifax, read a paper "On the Existence of a Reducing Endo-Enzyme in Animal Tissues". (See Transactions, p. 259). The subject was discussed by the PRESIDENT, Dr. A. H. MACKAY, PROF. MOORE, C. B. NICKERSON, and PROF. E. MACKAY.

A paper by HENRY S. POOLE, D. Sc., F. R. S. C., Guildford, Surrey, Eng., on "*Senecio jacobœa* and its parasite, *Callimorpha jacobœa:* the Ragwort and the Cinnabar Moth," with additional remarks thereon by the reader, was read by DR. A. H. MACKAY. (See Transactions, p. 279). The subject was discussed by DR. E. MACKAY, C. B. NICKERSON, W. MACKERRON, and others; and it was agreed that some steps should be taken to suppress such a noxious weed as the Ragwort. The matter was referred to the Council.

Second Ordinary Meeting.

Civil Engineering Lecture Room, Technical College, Halifax; 19th January, 1914.

The President, D. M. Fergusson, in the chair.

It was reported that on 28th November, Stanley Newlands Graham, B. Sc., professor of mining, N. S. Technical College, Halifax, had been elected an ordinary member, and E. Chesley Allen, Yarmouth, N. S., an associate member.

Herbert Bradford Vickery, Dalhousie University, read a paper entitled "Notes on the Analysis of 'Ironstone' from the King's Quarry, North West Arm, Halifax". (See Transactions, p. 209). The subject was discussed by the President, Dr. E. Mackay, C. B. Nickerson, Dr. Bronson, Dr. A. H. MacKay, and H. Piers; and a vote of thanks was presented to Mr. Vickery.

Third Ordinary Meeting.

Civil Engineering Lecture Room, Technical College, Halifax; 16th February, 1914.

The President, D. M. Fergusson, in the chair.

A paper by Sidney Powers, Geological Museum, Harvard University, Cambridge, Mass., on "The Geology of a Portion of Shelburne County, Southwestern Nova Scotia," was read by Prof. McIntosh. (See Transactions, p. 289). The subject was discussed by Prof. McIntosh, the President, H. Piers, and others.

A paper by Frank W. Dodd, C. E., of the Whitehead Torpedo Works, Weymouth, Eng., entitled, "Additional Notes on 'Integral Atomic Weights,' " was read by Prof. E. Mackay, (See Transactions, p. 223). The discussion which

followed, was taken part in by the PRESIDENT, DR. A. H. MACKAY, PROF. E. MACKAY, and C. B. NICKERSON.

Votes of thanks were passed to the authors of these two papers, MESSRS. POWERS and DODD.

FOURTH ORDINARY MEETING.

Civil Engineering Lecture Room, Technical College, Halifax; 9th March, 1914.

THE PRESIDENT, D. M. FERGUSSON, in the chair.

JOHN H. L. JOHNSTONE, B. Sc., demonstrator of physics, Dalhousie University, Halifax, read a paper, "On the Electrical Properties of Acetic Acid in the Solid and Liquid Phases". (See Transactions, p. 191). The subject was discussed by DR. BRONSON and PRESIDENT A. S. MACKENZIE.

PROFESSOR DAVID FRASER HARRIS, M. D., D. Sc., F. R. S. E., Dalhousie University, read a paper on "Coloured Thinking". (See Transactions, p. 308). The subject was discussed by the PRESIDENT, DR. E. MACKAY, PRESIDENT MACKENZIE, H. PIERS, DR. A. H. MACKAY, and others.

FIFTH ORDINARY MEETING.

Civil Engineering Lecture Room, Technical College, Halifax; 20th April, 1914.

THE VICE-PRESIDENT, DR. A. H. MACKAY, in the chair.

PROFESSOR L. C. HARLOW, B. Sc., Provincial Normal College, Truro, read a paper on "Analyses of Nova Scotian Soils". (See Transactions, p. 322). The subject was discussed by the CHAIRMAN, G. F. MURPHY, PROF. D. S. McINTOSH, W. McKERRON, and H. PIERS.

Sixth Ordinary Meeting.

Provincial Museum, Technical College, Halifax; 18th May, 1914.

The President, D. M. Fergusson, in the chair.

A paper by A. H. MacKay, LL. D., F. R. S. C., on "Phenological Observations in Nova Scotia, 1913", was read by title. (See Transactions, page 347).

Harry Piers,
Recording Secretary.

TRANSACTIONS

OF THE

Nova Scotian Institute of Science,

SESSION OF 1913-1914.

On the Existence of a Reducing Endo-Enzyme in Animal Tissues.—By D. Fraser Harris, M. B., C. M., M. D., B. Sc., (Lond.); D. Sc., (Birm.); F. R. S. E., *Professor of Physiology and Histology* in the Dalhousie University, Halifax, Nova Scotia.

(Read 10 November 1913)

I. Historical.

It has for many years been recognized that both living and "surviving" animal tissues possess deoxidizing or reducing powers.

Hoppe-Seyler(1)in 1883 was the first to draw attention to the presence of powerful reducing processes in living tissues. He suggested that, through reduction, molecular oxygen was rendered active by conversion into nascent oxygen and thus enabled to oxidize certain constituents of tissues after the manner in which hydrogen-saturated palladium-foil can oxidize indigo.

Paul Ehrlich(2)two years later published his researches on the reducing powers of tissues during life and at the moment of death.

He classified tissues as regards their oxygen-avidity as follow:—

1. Those in which indo-phenol blue remains unchanged: these he regarded as saturated with oxygen. Examples; heart, renal cortex and the grey matter of the central nervous system.

2. Those which reduce indo-phenol blue to indo-phenol white, but not alizarine blue to alizarine white; Examples: striated and non-striated muscle, gland parenchyma.

3. Those which reduce alizarine blue to alizarine white, that is those with the greatest oxygen-avidity. Examples; lung, liver, fat-cells and the gastric mucosa.

Ehrlich injected the pigments subcutaneously *intra vitam*; he noticed that a certain degree of heat arrested the reducing-power, but he did not suggest that tissue-reduction was due to an enzyme.

Between 1888 and 1909 J. de Rey-Pailhade(3) wrote on a substance he called philothion which he regarded as one of the mercaptans and indistinguishable from cystëine. To this substance he attributed great importance in the fixation of oxygen by tissues.

Spitzer (4) in 1894 noticed that after the death of the animal, while the reducing powers of the tissues increased, the oxidizing capacity rapidly disappeared. He also noticed that the temperature of 100° C might not always destroy the reducing power, whereas it always destroyed the oxidizing.

In 1895 Sir Victor Horsley and A. Butler Harris(5) made a report to the Scientific Grants Committee of the British Medical Association on the appearance of tissues of animals injected subcutaneously *intra vitam* with methylene blue. In the milk and in the urine a leuco form was found. On faradization of the living cortex cerebri these workers demonstrated a state of reduction around the stimulated spot at a time when the blue coloration elsewhere was at its height. The

decoloration was not due to ionized hydrogen at the kathode, for when the cortical excitability had disappeared, the reduction of the pigment at a stimulated spot could no longer be obtained.

These workers therefore recognized the simultaneous activity of two processes oxidation and reduction, the precise colour at any moment being the result of the relative predominance of the one process over the other. Frequently they found that oxidation prevailed over reduction.

In 1896 I([5])*found that living tissues of cat and rabbit, —kidney, liver, heart, glands—reduced the blue pot-assio-ferric ferrocyanide in the Prussian blue and gelatine injection mixture to the green or white leuco state of the di-potassio-ferrous ferrocyanide which on exposure to air slowly, or by treatment with hydrogen dioxide rapidly, became blue again.

The pigment was reduced only in the washed out smaller vessels and capillaries; in presence of blood not washed out of the larger vessels, the Prussian blue remained unreduced. The colour of the blood was therefore a purple.

In 1899 the term "reductase" as indicating a tissue-ferment, capable of effecting reduction processes seems to have been first used by Abelous and Gerard.([7])

Pozzi-Escot([8])in 1902 published the results of work onthe reducing action of vegetable and animal tissues on solutions of indigo, litmus and Prussian blue out of contact with air. He confirmed Rey-Pailhade in finding that the tissues could form hydrogen sulphide from sulphur and could reduce potassium iodide when out of contact with air.

He held that a reductase might be suspected when a living tissue decomposes H_2O_2, but does not affect a mixture of guaiacum and H_2O_2.

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*At this date I had seen only Ehrlich's paper on oxygen avidity.

C. A. Herter[9] in 1904 and 1905 published two papers on the reducing powers of living tissues. He injected methylene blue *intra vitam*. He stated that "the liver usually retains a high grade of reducing activity for several hours after death." He found lung, suprarenal capsule and grey matter of central nervous system all reduced the blue to the leuco state. An animal which was chilled by wet cloths or ice "exhibited the powers of reduction much diminished by cold". Herter showed that, conversely, the reducing power of the tissues of an animal injected with the micro-organisms of a specific fever was increased.

Underhill and Closson [10] in 1905 confirmed Herter's views and came to the conclusion that their experiments demonstrated the simultaneous action of both oxidative and reducing processes in the animal organism.

In 1906 Professor J. C. Irvine and I[11] showed that the *intra vitam* reduction of Prussian blue was not a deoxidation, but the removal of an ionic charge.

By perfusing the surviving kidney of a sheep with the Prussian blue mixture, I obtained from the ureter an absolutely colourless artificial urine which was blued immediately on treatment with H_2O_2.

Authors with increasing frequency are recognizing the existence of reductase.

Oppenheimer [12], for instance in his large work on "Ferments" does so: most of the authors of text-books mention the reducing power of tissues even when they do not recognize "reductase".

Some, however, frankly postulate a reducing ferment; thus, G. P. Mudge[13] writes, "If an albino does carry a chromogenous body which only needs the influence of an oxidizing or reducing ferment to cause it to produce pigment", etc.

II. Materials used in Judging of Reduction by Tissues.

These may be classified as:—

1.(a)Those containing,and (b)those not containing oxygen.

II.(c)Those which are and (d)those which are not pigments.

A. *Pigments*: 1. Containing oxygen: haemoglobin; methaemoglobin; sodium-indigo-disulphonate.

2. Not containing oxygen: methylene blue; Prussian blue.

B. *Non-pigments*: 1. Those with oxygen, e. g., sodium nitrate.

2. Those without oxygen, e. g., ferric chloride.

III. Methods of Studying the Reducing Powers of Tissues.

All the following methods of bringing the pigments and other substances into contact with the tissues or tissue-juices, or other preparations of tissues have been tried: (a) immersing pieces of surviving organs in the test substances; (b) mixing the liquids with aqueous, saline or dilute glycerol so-called "solutions" of reductase; (d) injecting surviving organs with the Prussian blue and gelatine mixture; (e) perfusing this injection mass or, for instance, ferric chloride, through the vascular system of a surviving organ; (f) perfusing the blood-vessels, and obtaining in the case of the kidney, artificial urine, in the case of the liver, artificial bile.

As might be expected, the method merely of immersing pieces of tissue was by far the least satisfactory. No good results comparable with those got by Dr. Vernon (14) in the case of oxidase were obtained, but in this respect reductase resembles glycogenase, an undoubted endo-enzyme.

The routine method followed was to use the press-juice from a Klein's press. This was kept sterile under toluene. Its reducing power gradually declined in energy, until at the end of three months it had vanished.

Various extracts of organs were made—aqueous, saline and glycerol—but as their reducing power was considerably weaker than that of press-juice, these were not extensively used in examining the properties of reductase.

Injection of the Prussian blue and gelatine mixture into the blood-vessels of organs was not used on many occasions. It was, however, originally by this method that my attention was drawn to tissue reduction, as I suspected that the "fading" of the mixture in the capillaries of the parenchyma of liver and kidney was chemically of the nature of a reduction. This does not constitute a convenient method owing to the liability of the gelatine to "set" if the proper temperature is not maintained.

The revival of the blue colour in an injected and almost colorless kidney or liver cut open and exposed to the air or to the action of $H_2 O_2$, is striking when seen for the first time. The vessels on the cut surface begin to show up like letters written in "sympathetic" ink.

It was by this method that I obtained an artificial, gelatinous, leuco urine from the sheep's ureter: it became blue on treatment with $H_2 O_2$.

The method of injecting ferric chloride through the portal system and examining both the hepatic emergent fluid and the contents of the gall-bladder for ferrous chloride, in both of which it was found, proved a satisfactory method.

IV. Preparation of the Juice.

The following may be taken as typical of the technique. A liver removed from the animal (rabbit, cat, dog, pig) before the heat has left it, is perfused through the portal vein with tap water at 40° C or with 0.75% NaCl until the water from the hepatic vein is colorless. The organ is then rapidly cut into largish pieces from which a good deal of water is allowed to drain away. The pieces are then cut up into much smaller bits and forced into the juice-press in which they are crushed

under considerable pressure. A fawn coloured, viscid liquid drips out and is received under toluene. This juice is subsequently ground up with powered glass and filtered through two layers of cheese cloth to free it from connective-tissue and the debris of blood-vessels, etc. Some preventative of putrefaction must be used although any such substance reduces the energy of tissue-respiration.

V. Description of a Typical Observation.

Three cubic centimeters of *absolutely fresh* press-juice prepared as just described, were shaken in a test-tube with 10 c.c. of 0.05% solution of soluble Prussian blue at room temperature (about 17° C). The blue colour began to disappear immediately, and in less than a minute after passing through light blue, light green and greenish grey, the mixture became light grey in colour. No trace of pigment remained.

When the same volume of *boiled juice* was used, no decrease in the intensity of the blue coloŭr of the solution was observed at the end of several hours. The reducing activity of the juice was found to diminish somewhat rapidly with time. With a mixture containing 3 c.c. of the press-juice 24 hours old, and 10 c.c. of 0.05% Prussian blue solution, it was found that ten minutes elapsed before its colour became green grey, and two hours before it became completely colorless, (grey).

VI. Examination of Possible Fallacies.

Since the change from the coloured to the leuco condition is the sign of reduction having taken place, one must guard against confusing the fading of pigments through reduction with fading from causes other than bio-chemical reduction.

(a) The earliest criticism offered was that the fading of the Prussian blue was due to the presence of "alkaline salts". Now free alkali, which undoubtedly fades Prussian blue, does not exist in the tissues or their juices. The inorganic salts of tissues and tissue-juices do not bring about any fading of soluble Prussian blue.

Ringer's solution added warm to Prussian blue produces no change of colour beyond that due to a corresponding dilution with water.

None of the salts of the tissues, NaCl, KCl, Na_2CO_3, $Ca_3 2(PO_4)$, Na_3PO_4 in strengths under 1% solution added warm singly or in any kind of combination, caused any fading to the green or to the leuco condition, whereas the subsequent addition of such a reducer as pyrogallol at once caused fading through green to white.

When the gelatine and Prussian blue mixture is used to inject organs still living, the pigment is reduced, as I believe, by the agency of the living tissues; and histologists aware of this fading, attribute it to "contact with the alkaline salts of the tissues."

Thus Rawitz(16) recommends that a little acetic acid be added to the injection-mass to prevent the "fading" by alkaline tissues.

Naturally, this criticism applies only to pigmentary substances, and has no applicability to non-pigmentary salts used to demonstrate bio-chemical reduction.

(b) The next source of fallacy one must bear in mind is the possible putrefaction of the proteins of press-juice in in specimens of juice kept for more than a few days.

Toluene was the antiseptic used for all press-juices; some kind of antiseptic is absolutely necessary, although Battelli(23) has emphasized the inhibitory effect of antiseptics on the enzymic and respiratory powers of tissues. The antiseptic used had obviously to be one which would not of itself bleach or reduce the pigments or other substances and would not act as an activator or inhibitant of the enzyme. Sodium fluoride and many other substances had to be rejected on some of those grounds. Toluene apparently prevented putrefaction in the press-juices used. Had the reductions in old juice (two to six weeks old) been due to putrefaction or autolytic substances, then the reducing power should have

steadily increased with the age of the juice. But exactly the opposite was found, the longer the juice was kept under toluene the *less* it reduced until after ten weeks or so it did not reduce at all. But putrefaction would have been progressive, and therefore reduction due to putrefaction would have been *more* marked as time went on. I had, however, positive evidence of the absence of putrefactive micro-organisms in a specimen of liver juice three months under toluene, which was examined for me by Dr. Sholto Douglas of the University of Birmingham and pronounced sterile.

It seems clear, then, that the reductions studied were not brought about by the products of putrefaction or autolysis.

(c) As regards fallacies, another point to be remembered is that the substances employed—Prussian blue, ferric chloride, etc., are all more or less poisonous. We cannot, therefore, expect the living tissue to reduce unlimited quantities of such substances whether pigmentary or not.

Thus only the earlier portions of liquids emerging from perfused organs or being excreted into the gall-bladder or ureter should be examined for reduced material. Because a kidney perfused indefinitely long with ferric chloride does not continue to produce unlimited quantities of ferrous chloride is no evidence that it was not originally able to reduce some of it, for such substances, even in dilute solution, are more or less toxic to living protoplasm, especially in experiments in which that protoplasm is receiving no blood.

(d) The last criticism is that of A. Heffter ([17]) which is directed not so much against the methods of judging of reduction by the fading of pigments, as against the whole conception of tissue-reduction being enzymic in nature. Heffter holds that the labile H of colloids in such a grouping as cystëine is able to effect all the reductions observed. He says that crystallized egg-albumen can bring about many reduc-

tions. Heffter's contention is that proteins apart from life can actively reduce.

Confining ourselves first of all to Prussian blue, it is certain that all proteins do not cause this pigment to fade, at least within times measured by hours and at room-temperature. For one thing, gelatine itself without acid does not cause soluble Prussian blue to fade even before it is injected into an organ and even when heated.

It is well known that this injection-mass mixed with the blood-proteins in the large vessels of mammals at body temperature is not reduced or caused to fade. Neither is methylene blue; those pigments remaining blue produce along with the red of the blood *a purple* colour. If Heffter be correct, we should expect the blood-proteins to reduce these pigments to a pale green or leuco condition, this they certainly do not do.

If one mixes a saline solution of *pure* serum-albumen or serum-globulin with Prussian blue, no fading takes place at room temperature within 24 hours.

In 1912 my co-worker at that time, Dr. H. J. M.Creighton(18)of the Dalhousie University, Halifax, N. S., investigated this subject with very great care and published his results in the Transactions of the Nova Scotian Institute of Science.

Dr. Creighton showed that if one mixes 10 c.c. of a 15% solution of egg-white in dilute NaCl with 10 c.c. of a 0.05% solution of soluble Prussian blue (potassium ferric ferrocyanide) and keeps the mixture at 60° C the colour will have faded at the end of an hour. The fading is gradual. Dr. Creighton writes, "With pure white-of-egg at a higher temperature, the decoloration of the soluble Prussian blue was found to proceed with greater rapidity". On the other hand, white-of-egg solution and 0.05% Prussian blue mixed and kept at *room temperature*, showed no fading or change of colour at the end of six hours.

Dr. Creighton further showed that the iron ion originally trivalent in the soluble Prussian blue is divalent in the

colloidal complex of albumen and the pigment. There has therefore been reduction. Further, this colorless colloidal complex can be boiled for a short time without its coagulating. For convenience, I call these phenomena, "the Creighton effects". Now there is one significant difference as regards the interaction between proteins and soluble Prussian blue and the interaction between press-juice and that pigment, namely, that whereas there is no fading of the blue in the presence of protein at the end of many hours, the blue in contact with fresh juice fades *at once.* These are clearly not the same phenomenon; for one thing, in the case of the protein mixture the concentration of protein is very much greater than it is in press-juice, but its effect is very much slower.

Further, if the fading of the pigments is due to protein, then the juice kept for three months, in which the protein is well preserved and is sterile, should reduce as well or almost as well as fresh juice; but this is noticeably not so.

Again, the rapid falling off in potency as regards reduction within the first day would have no meaning as a phenomenon due to molecular groupings and labile hydrogen, whereas it has a meaning with reference to the deterioration of the biochemical activity of a ferment.

The fact that glycerol extracts of dried liver and of dried kidney possess some reducing power, is more in accord with the conception of that reduction being due to an enzyme than to a protein, for the glycerol extract of *dried* liver had some cognizable reducing power, and it could have taken up very little protein in "solution". Glycerol by itself has no reducing power.

Again, glycerol extracts deteriorate in potency with time for which there is no particular reason, if protein be the active substance. Blood at 40° C does not reduce ferric chloride, but liver-juice at this temperature reduces it to ferrous chloride. There are proteins in both. While giving due weight to Heffter's contentions, and indeed recognizing certain

phenomena of the fading of pigments in contact with proteins which I have called "the Creighton effects," I still believe that vital reduction is something distinct from these and is probably enzymic.

VII. Indications That a Tissue Endo-Enzyme exists

1. The first consideration regarding reduction being due to an enzyme is that, whereas quite fresh juice vigorously and older juice more gradually reduces several different kinds of chemical substances, boiled controls do not do so at all.

2. The behaviour of the juice in regard to temperature is the next point indicating the presence of an enzyme.

Its optimum is between 42° C and 46° C. Thus Herter found reduction processes were accelerated in the experimentally induced fever of hog cholera. As the temperature falls, the rate of reduction is diminished until *at zero* reduction is entirely *inhibited.* But at a temperature as low as minus 14°C, the reducing power is not destroyed; it is merely kept in check.

I have kept under observation a mixture of absolutely fresh liver-juice and Prussian blue, surrounded by a freezing mixture for 24 hours, without noticing the least degree of fading of the deep blue colour. On removing the tube from the freezing mixture, the colour was completely discharged by the time the juice had reached room-temperature (17°C).

Herter found in the intact animal that "the power of reduction was much diminished by cold."

A typical experiment may be quoted in connexion with temperatures.

Three water baths were brought to (a) between 40° and 41°C; (b) between 42°C and 43°C; and (c) between 44° and 45° C respectively. In each bath a tube was placed containing 3 c.c. of 24 hours old hepatic juice shaken up with 20 c.c. of Prussian blue all under toluene. In 6 hours the tube in (a) was green, that in (b) was green-white, the one in (c) was

quite white; twenty four hours later the tube in (b) was white. The behaviour of tissue-juice is compatible with its active constituent being an enzyme.

3. As judged by the Pozzi-Escot test, a reducing ferment is present in certain tissues; for pieces of tissue, but better their juices, decompose pure H_2O_2without affecting a mixture of guaiacum and H_2O_2.

That the press juice, for instance of liver, is more active than pieces of liver is in accordance with the findings of other workers on ferments. J. J. R. MacLeod(20)noticed this in the case of glycogenase, an undoubted endo-enzyme.

4. The reducing action is accelerated or augumented by the presence of alkaline salts of the tissues, which behave as adjuvants. Professor Irvine and I(11)concluded that reductase acted after the manner of pyrogallol, an organic reducer, in an alkaline medium.

5. In my recent work(21)on the action of protoplasmic poisons on reductase, I found that the acidity (concentration of H ions) was a more profound inhibitant of the reducing power than was toxicity. Concentration of H ions is well known as an inhibitant of the activity of certain enzymes; to this reductase would not form any exception.

The fact that reductase is not totally inactivated by certain virulent protoplasmic poisons—chloroform, sodium fluoride, nitrobenzene, formalin—makes reductase comparable with the ferment in the laurel leaf studied by Dr. Waller(24). Chloroform was found to kill the leaf, but to set free an enzyme which liberated HCN.

6. As a ferment, reductase is pretty easily inactivated by drying the juice in vacuo at 15°C and by precipitation from juice by alsolute alcohol. As might be expected, drying and alcohol injure it less in tissues than in press-juice.

It clings with considerable tenacity to the cell-proteins, which evidently guard it from inactivation by heat, by drying and by alcohol.

In regard to its sensitiveness towards alcohol, reductase is in marked contrast with glycogenase, which can be obtained in an active state even from livers which have been for months under alcohol. This power that colloids have of protecting enzymes is a well-known property of the relationship between these two classes of bodies.

As judged by the criterion of solubility, reductase is comparatively insoluble; it will not, for instance, dialyze away from the cell-proteins. But in that it can in some measure pass into solution in dilute glycerol, it cannot be regarded as entirely of an insoluble nature

The insoluble endo-enzyme is now fully recognized. Professor Adrian Brown tells me that phyto-enzymes of a non-soluble order exist, and according to Vernon([22])the oxidase of the liver is insoluble. He adds that its insolubility does not preclude its enzymic nature, as there is a good deal of evidence pointing to a similar property in some lipolytic enzymes.

VIII. Remarks on Tissue Respiratory Ferments.

Besides reductase, at least two other types of respiratory enzyme exist in the liver, to confine our attention only to the liver in the meantime, namely a catalase and an oxidase or a number of oxidases. A catalase has long been recognised in the blood and tissues; Creighton and I([25])recently wrote:—

"The existence of a catalytic enzyme in the mammalian liver is fully confirmed. The decomposition of $H_2O_2$is effected by this enzyme, and is not due to the presence of proteins or other organic matter in the press-juice."

Boiled juice gives rise to no decomposition of H_2O_2; and the amount of H_2O_2 decomposed bears no relation at all to the amount of protein in the juice, for a few drops of a very dilute juice reduced 97.2% of H_2O_2 in the first five minutes. No doubt it is possible that the two enzymes, catalase and reductase, may co-operate in hepatic reductions.

The presence of an oxidase, more probably of oxidases, must be remembered when one is working with the reducing ferment. As Dr. Vernon has shown, there are oxidases in the liver which must of necessity work in the direction opposite to that taken by the reductase.

Hence when we obtain a less distinct reduction than we expect, we have to remember that the oxidase may have been active. We have, in fact, the converse of the difficulty to which Dr. Vernon(14) alluded when, investigating "The quantitative estimation of the indophenol oxidase of animal tissues", he wrote: "The unavoidable presence of reducing substances, some of which are possibly enzymes or reductases which act in direct antagonism to the oxidases, and under certain conditions entirely overpower them. Hence the absence of an oxidizing action cannot be held to indicate the absence of oxidase unless the conditions are so chosen to give the oxidase the best possible chance of exerting its activity."

At an early stage I had noticed that in a tube in which the Prussian blue had been completely reduced to the leuco state, a re-establishing of the colour was evident from about the end of the first week onwards. A mixture of fresh liver-juice shaken up with pigment of suitable strength would begin to become blue again in spite of the fact that the mixture was covered by a layer either of toluene or of oil to the depth of an inch.

In the routine observations, I made no attempt to eliminate the oxidase of press juice, but in one experiment Dr. Lovatt Evans and I definitely arranged to exclude the physiological activity of that ferment. Accordingly we kept a sealed up mixture of liver-juice and Prussian blue at room temperature under an atmosphere of pure hydrogen in a completely reduced state for three and a half months. It never showed the slightest re-blueing; on breaking open the tube and adding H_2O_2 the contents immediately became bright blue. Exposure to the air produced the same result more slowly. Evidently the activity of the oxidase was prevented expressing itself owing to there being no oxygen for it to deal with.

According to Spitzer, the vigour of oxidase declines post mortem, whereas that of reductase increases for a time, but it is possible that the former phenomenon is the cause of the latter, the increase in the energy of the reductase being only apparent and due to the diminution of that of the oxidase working in the opposite direction.

Dr. Vernon, (14) fixing his attention on the tissue-oxidases, regards reducing ferments as troublesome intruders into his experiments. I, however, am forced to recognzie oxidases as forming as much a part of the cellular, respiratory, enzymic mechanism as are reductases.

It is in this connexion significant that the Cannizzaro reaction—the simultaneous oxidation and reduction of aldehydes—has been observed most frequently with liver tissue in the presence of dilute sodium bicarbonate and oxygen.

Possibly the "aldehydemutase" of Parnas is not one enzyme but a mixture of oxidase and reductase(23).

In some manner with which we are far from being fully acquainted, catalase, oxidase and reductase are all acting simultaneously in the living cells, carrying on the work of tissue-respiration. I have eliminated the activity of the oxidase for a sufficiently long time to allow the reductase untramelled activity; and conversely Dr. Vernon in his studies on oxidase has had to make due allowance for the presence of reducing substances.

Dr. Vernon and also Prof. B. Moore(25) have pointed out several respects in which oxidase differs from reductase.

It is perhaps too soon to formulate any theory of tissue respiration, but when the scheme is outlined it must be one taking cognizance of all the three respiratory types of enzymes and not a scheme framed in terms of oxidase alone.

Provisionally one might say that by reductase, oxygen is abstracted from tissue-lymph (more remotely from oxyhaemoglobin) and brought within the sphere of the activity of the oxidase which applies to it the oxidation of the carbon, hydro-

gen, sulphur, phosphorus, etc., in, or in the neighbourhood of, the living protoplasm.

With regard to haemoglobin, I have direct evidence that liver-juice can reduce this pigment from the fully oxidized two-banded condition to the fully reduced one-banded within a few minutes at 41°C. The quantities used were a test-tube full of solution of oxy-haemoglobin from freshly drawn defibrinated rabbit's blood, and three grams of freshly disintegrated liver squeezed before the animal heat had left it. This mixture was shaken up from time to time to distribute the juice, and within a minute or two, the solution had begun to lose its brightness which it steadily continued to do. The two bands in the spectrum became progressively hazier until at within ten minutes they had disappeared and been replaced by the single band of haemoglobin; shaking this pigment at once made the two bands re-appear; it was, therefore, reduced but still oxidizable.

A control, similar in all respects except that the juice was *boiled* for five minutes, showed no signs of being reduced at the end of 72 hours. This solution never did become reduced, but passed normally into the state of methaemoglobin.

A period of ten minutes may seem a long one in which to have to wait for reduction to haemoglobin, but we must remember that in vitro we have the entire mass of the solution finally fully reduced, while in vivo we never have the oxy-haemoglobin fully reduced in consequence of contact with the living tissues during only one transit of the blood. The blood is fully reduced only after the many transits in asphyxia.

I think, then, that we are justified in regarding the reductase as the respiratory ferment of the living tissues, the endo-enzyme, through whose reducing power oxygen is split off from the oxyhaemoglobin in the several capillary districts

It would seem to be the ferment which starts the process of internal respiration, oxidase that which continues and completes it.

IX. The Chemical Powers of Reductase.

In conclusion I should like to point out the true reducing character of the reductase of animal tissues.

(a) In the first place it is a typical deoxidizer in that it removes oxygen from osmium tetroxide and from such substances as oxyhaemoglobin, which is fully reduced, and methaemoglobin, which is reduced to the oxy condition.

(b) Substances containing oxygen, but not in a form wholly removable, can be reduced from the higher to the lower state, as when sodium nitrate is reduced to sodium nitrite,(25)or when sodium indigo-disulphonate and sodium alizarine-sulphonate are respectively reduced to their pale chromogens.

(c) The reductase can also reduce metallic salts containing no oxygen from their higher to their lower forms, as when ferric chloride is reduced to ferrous chloride(15). Here the change involved is the removal of an ionic charge from the trivalent ferri-ion which becomes the di-valent ferro-ion.

(d) Finally, certain pigments containing no oxygen such as soluble Prussian blue and methylene blue are reduced to the pale or white chromogenic conditions of the di-potassio-ferrous-ferrocyanide and methylene white respectively.

In all these reductions, the endo-enzyme is behaving after the manner of an inorganic reducing agent in an alkaline medium.

[The expenses of this research were met by a grant from the Government Grants Committee of the Royal Society, which is hereby gratefully acknowledged.]

BIBLIOGRAPHY.

7. Abelous and Gerard, Comp. Rend. Vol. CXXIX, p. 164, 1899.

23. Battelli Comp. Rend. Vol. CXXXVII, p. 1079, 1903. Do. Journ. de Phys., Vol. IX pp. 1,34,328,410,1907.

10. Closson, O. E. and Underhill F. P. Amer. Journ. Phys. Vol. XIII No. V., p. 358, 1905.

18. Creighton, H. J. M., Trans. Nova Scotia. Instit. Sc. Vol. XIII Pt. 2, 1912.

23. Dakin, H. D. Oxidations and reductions in the animal body. London Longmans, 1912.

2. Ehrlich, Paul. Das Sauerstoff-Bedürfniss des Orgniamus, Berlin, 1885.

6. Harris, D. Fraser, Proc. Roy. Soc. Edin. Vol. XXI p. 383.

6. Harris, D. Fraser, Jrl. Anat. and Phys. Vol. XXXI, p 381.

19. Harris, D. Fraser, Science Progress, No. 4, April, 1907.

21. do. Bio-Chem. Jrl. Vol. VI Pt. 2, p 200. 1912.

11. Harris, D. Fraser and Irvine, J. C., Bio-Chem. Jrl. Vol. I nos. 8 and 9, p. 355.

15. Harris, D. Fraser and H. J. M. Creighton, Bio-Chem. Jrl. Vol. VI, Pt. 4.

25. Harris, D. Fraser and H. J. M. Creighton, Proc. Roy. Soc. B. Vol. 85, 1912.

17. Heffter, A. Medizinisch-Naturwissenschaftliches Archiv. Bd. I. Heft. I. p. 81.
do. Archiv f. expr. Path. and Pharm. Festchrift. f. O, Schmiedeberg, p. 253, 1908.

1. Hoppe-Seyler, Berichte. d. deut. chem. Ges. Vol. CXVII, p. 1917, 1883.

5. Horsley, V and Harris, A. B. Brit. Med. Journ. Vol. II. p. 205, 1895.

9. Herter, C.A. Amer.Journ. Phys. Vol. XII.p. 128, 1904.
do. do. Amer. Journ. Phys. Vol. XII.p. 457,1905.
do. do. Proc. Soc. Exp. Biol. Med. Vol. II, 1905.

9 Herter, C. A. and Richards, A. N., Amer. Journ. Phys. Vol. XII, p. 207, 1904.

11. Irvine J. C. and Harris D. Fraser, Bio-Chem. Jrl. Vol. I Nos. 8 and 9, p, 355.

20. MacLeod, J. J. R. Amer. Journ. Phys. Vol. XXV. No. 5., 1910.

26. Moore, B and Whitely, E., Bio-Chem. Jrl., Vol. IV, nos. 3 and 4, p, 136, 1909.

13. Mudge, G.P. Proc. Phys. Soc. Vol. XXXVIII. p, 67.

12. Oppenheimer, C. Die Fermente und ihre Wirkung. Leipzig. Vogel. 1909.

8. Pozzi-Escot, Ann. Chem. Anal. Vol. VII, p. 260, 1902.

3 Rey-Pailhade J. de, Comp. Rend. Feb. June and July 1889.

Rey-Pailhade J. de, Bull. de la Soc; fr. de chim; pp. 165, 523, 1051, 1907.

Rey-Pailhade J. de, pp. 159, 568, 1908; p. 133, 1909.

16. Rawitz quoted in Physiological Histology, G. Mann, Oxford, p. 160, 1902.

4. Spitzer, Berlin, Klin. Woch. p, 949, 1894.

23. Stern and Battelli, Journ. de Phys., Vol. LX, pp., 1, 34, 228, 410, 1907.

10. Underhill, F. P. and Closson O. E. Amer. Journ. Phys. Vol. XIII No. 5, p. 358, 1905.

14. Vernon, H. M. Intracellular enzymes, pp. 135-144, London, Murray, 1908.

Vernon, H. M. Jrl. phys. Vol. XLII. Nos. 5 and 6, 1911.

24. Waller A. D. Proc. Phys., Soc. June 18, 1910. Jrl. Phys. Vol. XL.

22. Vernon H. M. Jrl.Phys. Vol. XLIV. No. 3, 1912.

SENECIO JACOBAEA AND CALLIMORPHA JACOBAEA (*the Cattle Killing Ragwort and the Cinnabar Moth*) BY HENRY S. POOLE, D. SC., Guildford, Surrey, England.

(Read 10th November 1913.)

Some sixty or more years ago a plant strange to Nova Scotia, known as St. James Ragwort, Ragwort, Baughlan, Staggerwort, and Stinking Willie, was noticed growing at Merigomish and to be spreading over the neighborhood. Its seeds were supposed to have come in the ballast of timber ships. The speculations as to its origin when first noticed gave place in the course of time to invidious references more and more pronounced as the plant spread and invaded pastures and hayfields, scattering its seed freely in the Fall in total disregard of the spasmodic endeavors of farmers to extirpate it. It is included in the "Farm Weeds of Canada" by G. H. Clark and James Fletcher of Ottawa, 1902, and is spoken of as a noxious weed imported into Pictou county, Nova Scotia, whence it has spread in the course of years to other parts of the Province. Dr. A. H. MacKay in the Journal of Education for Nova Scotia, 1908, dwelt at length in his earnest endeavors to incite through the public schools, the farmers and their children in the infested districts, to a crusade against the plant. Prizes were given and he says millions of the seed were destroyed. The effort to exterminate it by this means, was, however, found ineffectual and consequently abandoned. Any steps that have since been taken to check the spread of the plant have been those of individuals on their own lands only. The roadsides, the burnt lands and the unenclosed woodlands have been left to the undisturbed possession of Stinking Willie.

In England, Ragwort is referred to in "Common Weeds of the Farm and Garden" by Harold C. Long, and in Weeds of the Farm and Garden" by Pommel. In these works and in ordinary life any reference to the plant is in mild terms. It is spoken of merely as one of the many weeds of the roadside, as a common weed and nothing more. It has been left to Nova Scotia to single it out for notoriety by a specially opprobrious name and for reference to its noxious character on the floors of the local parliament.

To botanists it is an interesting member of the Compositae with discal florets of thirteen rays.

To me, a native and long a resident of Pictou county, thoroughly familiar with its luxuriant growth and its objectionable characteristics, it came as a surprise to meet with Ragwort comporting itself as a modest weed on the commons and heaths of Surrey in small communities and often solitary. I met it first in company of a botanist, Mr. H. E. Lee, and to him I contrasted its unobtrusive deportment in England with its assertiveness in Nova Scotia where it takes more than its fair share of place in the sun and in the waste places of Pictou county.

I aroused Mr. Lee's interest by telling him of the burnt lands and the fence rows yellow with its golden blossom in Autumn and of the ineffectual attempts through the public school teachers to root it out and exterminate it, or at least to check its spread to other parts of the Province. I mentioned also, that, however effective might be a rotation of crops in the cultivated ground and the indiscriminate grazing of sheep in the pastures, the unenclosed deforested land was so large that all hope of extirpation by the hand of man and the teeth of sheep had to be abandoned. It was then he told me Ragwort had a natural and special enemy in the Cinnabar moth whose showy colouring had previously attracted my attention. This information at once suggested that if the fact as stated to me was sustained on further inquiry and the

knowledge proved to be as new to the Canadian agricultural authorities as it was to myself, then it would be worthy of further investigation.

To this end I spoke to the Director of the Royal Botanic Gardens at Kew, Sir. E. D. Prain, and to officials in rooms four and eight of the Department of Agriculture and Fisheries, Whitehall Place, and also to Mr. R. South, F. E. S. of the Natural History Museum, South Kensington. In the meantime I had made acquaintance with Mr. I. W. Walton, the botanist, at Folkestone, who confirmed from local observation the statement made by Mr. Lee. Any lingering doubt I may have had was removed on visiting the Natural History Museum and reading the slip attached to the specimens of *Callimorpha Jacobaea*, the Cinnabar moth of the order Heterocera.

Seeing that none of the works on weeds already quoted made reference to the Cinnabar moth, attention was turned to Barret's Lepidoptera of the British Isles, a standard work, and on page 246 the moth is spoken of as common in England and as having been taken as far North as Perth. It was also mentioned that while the moth is generally met with on Ragwort, it has occasionally been found feeding on the Coltsfoot.

At this stage of my inquiry several questions presented themselves: among them first, was the Cinnabar moth known in any part of North America?

Inquiry of the Bureau of Entomology, Department of Agriculture, Washington, U. S. A., brought a courteous reply from Dr. F. H. Chittenden to the effect that he has never found *Callimorpha Jacobaea* to occur in the United States at all; and he further wrote that on referring the matter to Dr. H. D. Dyar a specialist on Lepidoptera in that group, he stated that he has never known of its being taken in the United States.

This reply suggested in turn a second question—might the Cinnabar moth if introduced into Canada become as disastrous an importation as the gypsy and brown-tailed moths had proved to be? I referred this question to Mr. South of the Natural History Museum, and he had no hesitation in saying he saw no reason to dread the introduction of the Cinnabar moth. It was not of a class to become a pest as the narcissus fly or the larch saw-fly. He further permits me to quote him and to refer to him if need be.

A third question that presents itself is—what are the prospects that the Cinnabar moth will, if introduced into Nova Scotia, to establish itself there? To this, all that can be said without actual trial is, that the moth survives in the climate of Perth in a latitude far to the north of Pictou. Then it may be asked if the moth should be found to stand the climate of Nova Scotia, is there a probability of its abandoning its European predilection for Ragwort and taking to feeding on other allied species of plants?

About the time that Ragwort established itself at Merigomish, cases of hepatic cirrhosis occured among cattle of the same district. This was a new disease, entirely local, that yielded to no known treatment. Current belief imputed the disease to the weed but up to the end of the last century investigations had failed to establish a connexion. As the weed spread and flourished in new ground so did the disease range over a widening area from new centres of virulence.

These new centres were in some cases places where the weed had been growing for very many years without an occurrence of the disease, or if there was a case, it was a solitary one, which inquiry showed had lately come from an infected locality. Since the present century came in the spread of the disease seems to have been more rapid, and in remote districts beyond the height of land that isolated, as it might be said, the primarily infected area.

Ragwort being a biennial has no chance of flowering and seeding in the pastures grazed over by sheep which are close

croppers, and are in consequence a check on the spread of the weed in enclosed lands. Horses too, are not known to be affected by it for they not only avoid it in the field but also where they find it in the hay. Cattle, on the other hand, while more discriminating in their feeding than sheep, are careful to avoid eating it in the open but they have not the same opportunity for rejecting it when it is dried and mixed with hay in the byre. It is then they suffer, and it is now stated on page 161 of "The Farm Weeds of Canada" that Dr. Pethick of Antigonish has proved that Ragwort is the cause of the Pictou County Cattle Disease. This being so it is all the more apparent that trial should be made of any means that may reasonably be expected to further check the spread of so noxious a weed in Canada.

When commenting to me on the relation of Ragwort with the Pictou County cattle disease Sir. E. D. Prain related an Indian experience that was apposite to the matter. Speaking of the use of sorghum as forage when the plant was fully grown and cut down, he remarked that care was necessary to keep cattle from the fields while the plant was still young as it then contained hydrocyanic acid in poisonous quantity. Not so when the sorghum was well grown, but it sometimes happened that the season was wet after the harvest and then instead of drying, the plant sent up fresh shoots which were as poisonous to cattle as the young plant.

It would have been superfluous and presumptuous on my part to dwell on the relation between the Cinnabar moth and Senecio when so great an authority as the Natural History Department of the British Museum accepts it without reservation.

Mr. C. W. Brachen, B. A., F. E. S., of Plymouth writes me as follows:

"I have met the larvae of the Cinnabar moth, when sweeping, for years, but only on Ragwort and Groundsel (*S. vulgaris*). I have never seen it on Coltsfoot. It can be

found in hundreds in Turnchapel Quarries, Plymouth, at Newton Ferrars, Hessenford, everywhere round here probably. I have found it more common near Ragwort though I have made no special comparisons."

Larvae of Cinnabar Moth (*Callimorpha Jacobaea*).

Food Plant: Commonly, the Ragwort (*Senecio Jacobaea*).

The larvae usually attack the lower leaves first and work upwards towards the flower. They frequently strip the lower portion of the plant completely, and in a very short time. Large colonies are often seen on one plant; and the striking colouring of the larvae make them conspicuous even at a little distance.

Remarks by Dr. A. H. MacKay.

Senecio Jacobaea L. (St. James Ragwort), was probably introduced into Pictou, Nova Scotia, not far from 1850. Shortly after, the Cattle Disease appeared. But it did not follow the presence of the weed until after it became well established in the pastures and hayfields. About 1882 there was an attempt made by the Dominion Government to ascertain the character, cause and best method of dealing with the disease which was recognized as a peculiar and almost specific cirrhosis of the liver. It was, however, suspected to be contagious; and the policy of slaughter and compensation was adopted. Drs. William Osler, Adami, Wyatt Johnson, McEachran and other pathologists took part in the earlier investigations.

In 1906 Dr. J. G. Rutherford as Veterinary Director General, reports Dr. W. H. Pethick's experiments on a 200 acre farm at Cloverville in Antigonish county. He also notes that Dr. Gilruth of New Zealand devoted considerable attention to a peculiar hepatic cirrhosis known as the Winton Disease, from which horses as well as cattle and sheep suffered due to the ingestion of Ragwort. In Cape Colony, South

Africa, *Senecio Burchelli* appeared to produce similar effects. Last year another species, *Senecio latifolius,* in South Africa appeared to have poisonous properties according to the kind of soil in which it grew. Dr. Pethick's experiments appeared to prove that the disease is not contagious, and is due to the ingestion of the Ragwort with hay eaten.

Professor Arthur R. Cushney of the Pharmacological Laboratory, University College, London, England, lately experimented with the Senecio alkaloids and makes the following statements in two papers published in 1911.

1. "On the Action of Senecio Alkaloids and the causation of *Hepatic Cirrhosis* in Cattle (Preliminary Note)" Read 15 June, Proceedings Royal Society B. Vol. 84; and

2. "On the Action of Senecio Alkaloids and the causation of the *Hepatic Cirrhosis* of Cattle (Pictou, Molteno, or Winton Disease), published 10 June, in the Jour. of Pharmacology and experimental Thearapeutics, Vol. II, No. 6. July, 1911.

(1). "The various species of Senecio in this country are generally regarded as harmless, the chief of them being the common ragwort and the common groundsel. In Nova Scotia, New Zealand, and South Africa they have, however, been associated with hepatic cirrhosis in cattle, which is known as respectively Pictou, Winton, and Molteno disease in these countries. The species which induces this condition in Canada and New Zealand is apparently identical botanically with the common ragwort of this country, *Senecio Jacobea,* while in South Africa the Molteno disease is associated with the *Senecio Burchellii* and the *Senecio latifolius.* The symptoms of the disease are practically identical in these locations."

(2). "With regard to the chemistry of the *Senecio* genus, Grandval and Sejour found two alkaloids in the common groundsel which they term senecionine and senecine, and Watt found two others in the *Senecio latifolius* of Cape Colony,

and has named them *senecifoline* and *senecifolidine.* These alkaloids amounted to 1.72 per cent. of the plants in the crude state before flowering, and 0.76 per cent after flowering. These two bases were sent to me for pharmacological examination by Prof. W. R. Dunstan, and I have done a number of experiments with them, chiefly upon cats."

(3). "The symptoms and post mortem findings in animals poisoned with these alkaloids resemble so closely those described by Gilruth, Chase, Pethick and others, in cattle and horses, that there can be no question that the cause is the same in each and that the Pictou, Winton or Molteno disease is really more or less chronic poisoning with the Senecio alkaloids."

(4). "The experiments hitherto detailed were performed with the alkaloids of *Senecio latifolius*, which, as has been said, is held responsible for some of the epidemics in South Africa; and my results indicate that these alkaloids are capable of inducing the symptoms and lesions characteristic of the disease. The *Senecio Jacobœa* which has been shown to be responsible for the disease in New Zealand and Canada, grows in profusion in England and Scotland, but inquiries made in various parts of the country indicate that poisoning with this plant and hepatic cirrhosis are unknown here."

(5). "These results would therefore seem to indicate that the *S. jacobaea* is devoid of the toxic properties of *S. latifolius*, whether the plant is grown in England or in Canada. This is however incompatible with the results of Gilruth and Pethick, who showed definitely that the disease in Canada and New Zealand is due to this species. The discrepancy between these results and mine may probably arise either from the plant from which my preparations were made having been collected at the wrong season, or possibly from the poisonous principle having undergone change into some inert form in the course of preparation or drying."

(6). "*Senecio sylvaticus* collected in Yorkshire in August proved equally inactive. *Senecio vulgaris* or common groundsel collected in England and prepared in the same way proved poisonous."

(7). "I hope to investigate further the toxicity of *S. jacobaea* with the hope of elucidating the curious discrepancies between my results and those of Gilruth and Pethick."

(8). The following statement has just been made by Professor Cushney in an autograph note on one of the said printed papers in October, 1913. "Later experiments with the alkaloids derived from the *S. Jacobaea* grown in Canada have shown that they are quite as poisonous as those obtained from *S. latifolius*" (Oct. 1913).

The weed is rapidly spreading throughout the Province, and the appeals to municipal councillors have not yet incited any effective action. Sheep are not so seriously affected by the plant; but there is evidence that it is injurious to them. The plant grows luxuriantly and, although it is popularly known as "Stinking Willie", it is one of the most beautiful of our weeds, the abundant pretty green foliage being surmounted by a brilliantly yellow flat-topped cluster of compound flowers.

If the Cinnabar moth could repress the luxurious growth of *S. Jacobaea* in Nova Scotia, it would require to multiply rapidly and feed ravenously.

But, what if the larvae of *Callimorpha Jacoboea* should take to feeding upon the plants of economic value? What if they should develop here as the Gypsy Moth and the Brown Tail? The English Sparrow first introduced about 1850 has long become too vigorous for America. The European rabbit introduced into Australia in 1864 for sport, increased so rapidly as to require legislation in 1879 for its destruction. The Mongoose of India introduced into Jamaica in 1872,

by 1890 became a pest. The European Starling introduced into New Zealand in 1867 in a few years began to show itself as an undesirable. The skylark, the linnet and the blackbird of England, have in the antipodes developed new food habits, and instead of being insect destroyers as at home, are becoming fruit pests.

Can we therefore venture to invite the Cinnabar Moth to Nova Scotia? Test the new conditions might develop a taste for something more than the succulent foliage of St. James Ragwort.

The Geology of a Portion of Shelburne Co., Southwestern Nova Scotia.—By Sidney Powers, *Geological Museum, Cambridge, Mass.*

Read 16 February 1914.

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Introduction.

This paper represents the results of a brief geological reconnoissance along the shore of Southwestern Nova Scotia from Jordan Bay to Barrington Passage, made during June 1913. The object of this reconnoissance was to study the structural geology, but outcrops were found to be few in number, and to be practically confined to the wave-beaten ends of the peninsulas, and therefore the work was not extended farther. As the only detailed previous examination of the region was made by Dr. L. W. Bailey in 1891 to 1896*, it is thought that this paper may form a contribution to the knowledge of the region. The structural details and the petrography of the igneous rocks were not considered in Dr. Bailey's report

The general geologic features of the region consist in a series of pre-Cambrian metamorphic quartzites and schists intruded by Devonian granites which have produced extensive contact metamorphism in the already regionally metamorphosed and folded sediments. Glacial deposits now cover the surface allowing the geologist only an occasional glimpse at bed rock.

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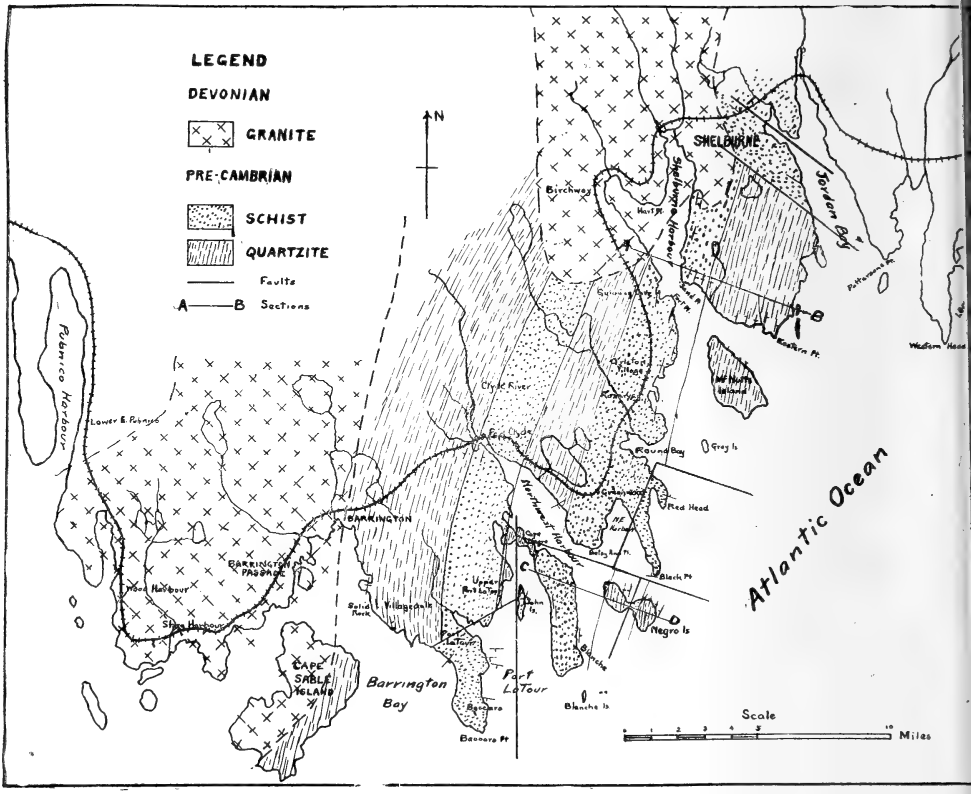
* Report on the Geology of Southwestern Nova Scotia; Canadian Geological Survey, Ann. Rept. Vol. 9, Pt. M, 1898.



Physiography and Glacial Geology.

Southwestern Nova Scotia is a low, rolling country indented by an embayed shoreline. Numerous lakes, often of large size, and more numerous peat bogs representing former lakes cover the low-lying areas. Where these are absent, boulders characteristically cover the land, representing the ground moraine. Such a topography determines the occupation of the inhabitants of the country, preventing agriculture and promoting fishing and boat-building. The low hills are covered by a dense, but low, forest of spruces and balsams which effectually conceal the view. Frequent forest fires, due to the carelessness and wilfulness of the inhabitants,

prevent the growth of mature forests and leave in their wake a scene of desolation—burned villages and square miles of charred tree trunks laying bare the boulder-strewn ground moraine.

The present topography of the region is due to the dissection and drowning of the Cretaceous peneplain and to glaciation. The peneplain was uplifted probably toward the middle of the Tertiary and suffered erosion throughout the remainder of the Tertiary. The land during this period appears to have stood higher than at present, long valleys being formed which are now drowned. These valleys were formed without respect to geological structure because the rocks have about a uniform hardness and have been sufficiently metamorphosed to obliterate the primary structure and yet not to produce pronounced cleavage. The submergence of the land to its present level took place at about the time when the Pleistocene ice sheet advanced over Nova Scotia. The submergence did not go below present sea level because there are no marine beaches or wave-cut terraces above those being formed at present. In the Bay of Fundy region there is evidence of a recent uplift as is shown by the presence of marine fossils in beaches 200 feet above water level. It is therefore evident that there has been a differential uplift of the land in the latter region. This tilting must have been at least as great as two feet to the mile, as it is 108 miles from Shelburne to St. John where the elevated beaches are found.

The effect of glaciation has been to modify the topography. Glacial erosion can be measured in at least tens of feet, for everywhere the pre-Glacially weathered rock has been removed, and the bed rock scoured and channeled. Roches moutonnées are very frequent where wave action has removed the glacial deposits. These rounded knobs are especially noticeable at Port La Tour, forming islands at the entrance to the harbour.

Glacial deposits, other than the ground moraine, are largely of stratified drift. Eskers are the most striking phenomenon, but kames are also present. The character of the deposits must depend upon the kind of material with which the ice has to work. In the peninsula of Nova Scotia are soft Triassic sandstones and hard traps, developed only in a narrow band; fossiliferous Lower Devonian shales; and pre-Cambrian quartzites, slates and schists; the latter two series being invaded by the micaceous granitic rocks which form the central axis. The Triassic and Lower Devonian sediments would not furnish material for distant transportion and the traps would suffer little from glacial erosion. Therefore, for Shelburne County there was available a large quanity of sand derived from the granite and quartzite, and some sand and clay from the schist and slate, as well as massive material of each of these rocks. Hence, the ground moraine in this region is composed almost entirely of sand and boulders, drumlins being absent. Large deposits of sand are found at Villagedale, south-east of Barrington, forming numerous sand dunes 30 feet in height. The grains of sand consist largely of quartz with some pink feldspar, muscovite, and biotite, showing that they were derived from the granite nearby. Sandplains do not occur.

Eskers were observed at Shelburne, Roseway, Cape Negro and Port Clyde. The esker in Shelburne extends from near the Shelburne House in a N 10° E direction for about 1,000 feet. Its height varies from five to fifteen feet. Boulders and gravel appear on top of the ridge, the boulders having a length of two to three and a half feet. Near Roseway there are several eskers running nearly due south, the most prominent one being near the shore. This esker is about one-quarter of a mile long, 25 feet high and 75 to 100 feet wide. It forks at the south into two ridges. On the top of the esker are boulders 4 feet long, 3 feet wide and 3 feet thick. North of Port Clyde are abundant eskers, some of which have an east-

PLATE I.

View of Shelburne Harbor and Sand Point taken from Fort Point. In the distance, on the left, is the lighthouse on Sand Point and beyond it is Shelburne. The peneplained hills in the distance rise to an elevation of 200 feet. In the foreground is a glaciated ledge of staurolite schist whose bedding strikes toward Sand Point. The two erratics on the roche moutonnée are Shelburne granite. One has been almost quarried away—the usual fate of erratics in this country.

west elongation. North of Cape Negro is an esker two miles long with the main highway running on the crest. It runs across a swamp in a north-south direction, turning S 10° W at the southern end. In one place the ridge disappears for 50 feet, and in another it divides to pass around a kettle hole 100 feet long and 60 feet wide. At the south end it apparently expands into a poorly defined gravel plain. Another esker connects Cape Negro with the Blanche peninsula. Here again the road follows the esker ridge for three-quarters of a mile. The esker is 5 to 25 feet high and 50 to 100 feet broad. Northwest of Baccaro Point is an esker crossing a marsh, with a road on its top. This esker runs in a southerly direction for half a mile with a height of 20 feet and a width of 60 feet.

Everywhere in Shelburne County boulders are to be found. The largest are west of Shelburne. At the side of the railroad here, may be seen granite boulders 35 feet long, 25 feet broad and 20 feet high. This size of boulder is not infrequent, but more abundant are somewhat smaller ones, 10 to 25 feet long, lying not far apart, yet not forming a boulder moraine. To emphasize the size of the boulders, it may be stated that all the granite for the two story granite post-office building in Shelburne was quarried from a single one.

In the region between Barrington and Roseway, which was burned over in August 1911, boulders about two feet in length are everywhere scattered over the surface, as abundantly on the eskers as elsewhere. They are composed principally of the kind of rock found nearby. It is everywhere characteristic of these boulders to have rounded surfaces, and yet not to evidence distant transportation. Only one boulder was found of a rock not represented in the area by a closely allied type. This was a diorite found north of Gunning Cove.

The direction of ice movement in the region was, judging from the striae, in a S 10° E direction in general. The striae

noted are: in the vicinity of Sand Point and Fort Point (opposite Sand Point) N-S to N 5° W; a mile east of Greenwood N 5° W; at Black Point N 15° W; Negro Island N 8° W with an apparently earlier set of striations in one place of N 40° W; a mile north of Blanche N 10° W; near Port La Tour N 27° W; near Baccaro N 12° W to N 27° W; near Baccaro Point N 25° W and one outcrop N 40° W; at Barrington N 12° W.

Sedimentary Rocks

The southern and western portions of Nova Scotia are largely underlain by a series of quartzites, slates and schists, called the Meguma or Goldbearing Series. The age of these rocks is pre-Cambrian. The series has been divided lithologically into two conformable formations, the quartzite division at the base being called the Goldenville formation, and the slate above, the Halifax formation. The thickness of the former has been found by Faribault to exceed 23,700 feet, and the thickness of the latter is 11,700 feet, giving a total thickness to the series of nearly 7 miles with no base exposed.

In Shelburne County these two formations are represented by quartzites, some of which show the effects of contact metamorphism, and by schists, all of which are filled with metamorphic minerals. The exposures are so few and the faults so numerous that it is impossible to measure the thickness of the series. Their general distribution may be seen on the accompanying map.

The first exposure of the metamorphic rocks south of Shelburne is found on the shore halfway to Sand Point. Very fine-grained grey mica schist cut by aplite veins occurs here within a short distance of the granite. Approaching Sand Point, staurolites and large mica crystals begin to appear in the rock. At the point are large ledges and roches moutonnées of a lustrous schist containing numerous staurolite prisms a quarter of an inch in length, very abundant smaller biotite crystals all orientated parallel to the schistosity, and very

small garnets. Certain harder places in the surface of the rock stand up as small rectangular pinnacles one inch in diameter and three to four inches high, undercut below the hard capping which is only one quarter of an inch thick. The top of these caps are remnants of the smooth surface left by the ice. Such deep post-Glacial erosion is favored in this locality by the soft nature of the sericitic ground mass of the schist. The strike of these rocks averages N 25° E with a dip of 75° S.

A half mile east of Sand Point the schist is replaced by quartzite of light grey color and fine grain in which are occasional quadrangular biotite crystals about one quarter of an inch on a side (perhaps secondary after hornblende), staurolite crystals one half inch long, and occasional pink andalusites one inch long. The dip of the beds changes from 70°-85° S to vertical.

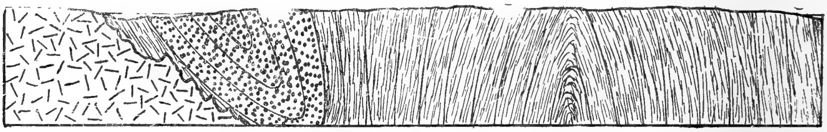
For a mile to the south much of the quartzite does not show large metacrysts*, though small biotites still persist. At one locality a mile and a half south of Sand Point,staurolite-biotite quartzite reappears. The staurolites are of usual size, but few in number. The biotite metacrysts are about one-sixteenth of an inch in length. Under the microscope the rock shows a fine ground-mass of quartz and sericite, meta-crystals of biotite free from quartz inclusions, a few garnet crystals, and accessory chlorite, apatite and iron ore. The sericite is more abundant near the biotite than elsewhere. The strike of these rocks is N 15° E, the dip 75° N.

From the outcrop just described to the end of Eastern Point, the rock is everywhere a dense grey quartzite free from metacrysts. Interbedded in the quartzite are a few bands of mica schist one to three feet wide. The structure here is anticlinal, the dip of the bedding being vertical near the "Tea Chest", a mile and a quarter north of Eastern Point with a dip of about 75° N on the north, as above stated, and

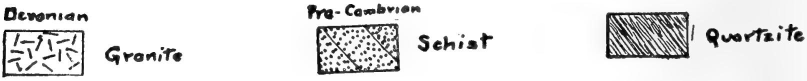
*A term introduced by Lane to designate the phenocrysts of metamorphic rocks which are formed after the groundmass. See the Bull. Geol. Soc. Amer. Vol. 14, 1903, p. 369.

a dip of about 80° S on the south. The strike is persistently N 15° E. The southern limb of this fold has been traced on the southwest through McNutt's Island and on the northwest through the towns of Lower Jordan Bay and Jordan Bay, but north of here a fault apparently cuts off the beds, as the strike changes to N 70° W and the dip to 40° N.

The structure of the peninsula is interpreted as a syncline in the schists on the north and an anticline in the quartzites on the south as shown in the section, Fig. 1. The pitch of the axis of the syncline is about 70° S. The syncline is cut off on the north by the granite, and the southern flank of the anticline disappears under the sea. On the opposite side of the Jordan fiord, Bailey found a few outcrops which indicate an anticlinal axis running in a N 60° E direction and starting about a mile north of Patterson Point. This anticline is separated from the one at Eastern Point by a northwest-



(Fig. 1.) Section through Sand Point and Lower Jordan Bay



southeast fault, and between these two large segments, on the north, there appears to be a block about two miles wide with a monoclinal dip at a rather low angle in a N 20° E direction. It is worthy of notice that at Western Head, 6½ miles east of Eastern Point, Bailey found a quartz pebble conglomerate and ripple marks in the quartzite (op. cit. p. 56).

On the west side of Shelburne Harbor, the first outcrop south of Birchtown is of quartzite, free from metacrysts, at Gunning Cove. The strike is N 10° E, dip 55° S, indicating that this quartzite is folded up on the north limb of the syn-

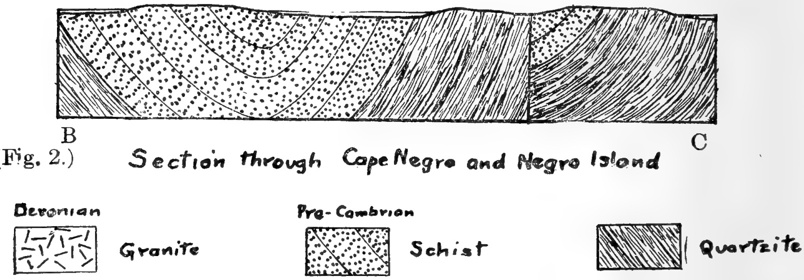
cline seen on the other side of the bay. It is noteworthy that this outcrop is within two miles of the granite, but shows no development of contact metamorphic minerals, owing probably to the dense texture and low alumina content of the rock. From Gunning Cove to Red Head (south of Round Bay), staurolite schist occurs in which the staurolites are of large size (one inch long), but not very abundant. The strike remains about the same, the dip being at a high angle toward the south until it changes to 75° N. east of Round Bay, on the southern limb of the syncline.

At Red Head staurolite schist outcrops, the staurolites being more abundant and of larger size than anywhere else in the region. Abundant biotites and small garnets are associated with the staurolites, and bands of the rock contain only biotite metacrysts. The strike is due E-W, and the dip at 3° N. indicating an east-west fault north of here. The same strike and a 10° N dip of the bedding is found at Black Point, three miles to the south. Here, also, the staurolites are abundant.

Negro Island consists of two islands joined by a sand bar. On the north shore of the eastern island staurolite schist appears on the west, near the lighthouse, and quartzite free from metacrysts on the east. The strike is about N 30° E with a variable dip of 15°-40° N. On the western island quartzites, locally containing a few staurolites, outcrop with a strike N 15° E, dip 70°-85° N. There is evidently a fault between the islands with a downthrow on the east, and also an east-west fault between the islands and the mainland.

On the mainland near Betsy Ann Point (separating Northeast and Northwest Harbors), a spotted grey ottrelite schist appears, with a strike of N 25° E, dip 30° N. It is a continuation of the southern flank of the syncline which has been traced from Sand Point. A fine-grained garnetiferous schist occurs a mile to the northeast and micaceous quartzite a mile and a half to the northwest. The same structure probably

continues into the Blanche peninsula, where mica schists with small garnets and occasional staurolites outcrop at Blanche and on the western side of the peninsula. In both places the strike was within a few degrees of due N-S, and the dip in the latter case 33° E. It is probable that the axis of an open syncline underlies Blanche as shown in the section, Fig. 2.



(Fig. 2.) Section through Cape Negro and Negro Island

John Island, west of the Blanche peninsula, is underlain by staurolite schists striking N 30° E and dipping 40° S.

At Port Clyde dark mica schist interbedded with micaceous quartzite forms an anticline with its axis striking N 20° E. Near Villagedale, on the western side of the Baccaro Peninsula, highly micaceous quartzite reappears striking N 15° E to N 15° W and dipping at a very high angle eastward. This is probably the same quartzite as at Port Clyde, appearing on the limb of a syncline. At Villagedale the quartzite is highly contorted by the granite which outcrops a short distance to the north. The large amount of muscovite and biotite and the small garnets in the rock were formed by recrystallization at the time of the granitic intrusion. Similar quartzite is reported by Dr. Bailey on the south eastern end of Cape Sable Island, indicating that part of that island consists of granite.

Near Port LaTour quartzite outcrops in several places but does not show any bedding. On the islands to the south, a number of roches moutonnées are found in which staurolite schist is exposed. The staurolites are about an inch in length

PLATE II.

The barren boulder-covered land north of Roseway, laid bare by the destructive fire of August, 1911. The boulders of this ground moraine consist of Shelburne granite, but the region is underlain by staurolite schist. Many square miles in Shelburne County consist of such land which is only good for forests.

PLATE III.

A detailed view of the staurolite schist at Crows Neck, south of Port LaTour. The staurolite prisms are mostly one to two inches long. At the base of the picture may be seen rounded masses of chlorite. The extent of post-glacial weathering is shown by the relief of the staurolites.

and quite numerous. The peculiarity of the rock hereabouts is the abundance of large patches of chlorite three to four inches in diameter, with rounded or quadrangular outlines. They have probably been formed as a replacement of hornblende, but no trace of the original mineral was discovered. A thin section of the rock from one of the islands shows a fine groundmass of quartz and sericite in which are large metacrysts of staurolite which enclose numerous quartz grains, large crystals of biotite which enclose small grains of quartz and titanite, metacrysts of garnet, some pennine and small amounts of iron ore and apatite. The strike of the rocks is due E-W with a dip of 20° S. The same staurolite schist continues around Baccaro Point, but quartzite appears on the Barrington Bay shore a mile west of Port LaTour.

Igneous Rocks

Micaceous granitic rocks occupy the central part of the peninsula of Nova Scotia, smaller masses appearing in numerous places from Halifax northeastward to Cape Canso, and also south of the main area. Two of the latter enter the area under consideration, at Shelburne and at Barrington. These batholiths consist respectively of biotite-muscovite granite and of quartz (biotite) diorite, with some pink aplitic granite in the immediate vicinity of Barrington.

The age of these granites is Middle Devonian; they cut the fossiliferous Lower Devonian slates of Clementsvale and of Torbrook-Nicteau, and the arkose derived from the weathering of these granites at Horton Bluff is found abundantly in the Horton Series which is of basal Mississippian age (Pocono, according to David White). The granites were intruded at the time of the Middle Devonian revolution which folded the Canadian Appalachian geosyncline and the region now embraced in the Maritime Provinces. The folding was not completed at the time of the intrusion of the granite because the latter shows the effect of a moderate amount of shearing.

Concerning the character of the granite in the neighborhood of the gold mines in Lunenburg and Halifax counties, where it has been studied the most, Mr. E R. Faribault writes*:

"The composition and texture of the granite varies much with the locality and mode of occurrence. The rock consists for the most part of a light grey or reddish grey coarse porphyritic biotite granite, generally studded with large phenocrysts of white or pink-white feldspar. In the west, a light pearl-grey or pinkish-white fine-grained muscovite granite occupies small areas penetrating the biotite granite as well as the sediments. With the muscovite granite are associated dikes of coarse pegmatite often passing to quartz, and bearing a large variety of minerals."

The Shelburne granite was observed in outcrops three miles south of the town, just south of the first outcrops of schist on the shore. The granite is porphyritic and includes fragments of schist. The schist is micaceous, a feature common to the sediments whenever near a granite contact, and it is cut by aplite veins one to three inches wide. Frequent outcrops of granite are found in railroad cuts southwest of Shelburne and at a quarry near Hart Point. The granite in the railroad cuts is cut by pegmatite dikes, the largest of which is three feet wide. Numerous pegmatite dikes are also found in boulders in this vicinity. The pegmatite consists of large pink orthoclase crystals (4 inches long, 3 inches wide and thick), masses of quartz in smaller quantities than the feldspar, plates of muscovite one inch in diameter, less abundant biotite crystals, a white feldspar showing albite twinning (probably oligoclase), garnets one-quarter of an inch in diameter, and occasional masses of tourmaline. One crystal of beryl, one and one half inches in width and length, was found.

The Shelburne granite is a light grey, fine-grained, micaceous granite with biotite generally predominating over

* International Geological Congress, Guide Book, 1, pt. 1, p. 168, 1913.

muscovite. When the mica, especially the muscovite, becomes more abundant, the rock has a slightly yellow tinge. The feldspar and quartz both occur in small grains, the former being white, and hence less conspicuous than the flakes of mica. Under the microscope the rock is seen to consist principally of xenomorphic crystals of feldspar and quartz, the latter showing undulating extinctions due to shearing, biotite in very numerous shreds and flakes between the other grains, accessory muscovite in occasional shreds both inside and outside the feldspars, and a few apatite crystals inside feldspars and muscovite crystals. The feldspar consists largely of oligoclase, with some albite-oligoclase (Ab_9 An_1) and albite-microcline microperthite. The results of a Rosiwal measurement of the rock will be found below. One slide shows a number of mermycitic intergrowths of the quartz and oligoclase feldspar. Some of the latter show zonal growths and occasionally undulating extinctions. The muscovite appears to be largely secondary, probably being developed by pneumatolytic action. In some cases it shows the same amount of shearing as the remainder of the rock and is therefore thought to be primary.

The Barrington batholithic area contains two kinds of rock, a pink aplitic granite at Barrington, and a biotite quartz diorite elsewhere. The relation of these two rocks is not known, only two exposures of the former being found, and a few of the latter. It is to be inferred from the relation of similar rocks elsewhere, as shown by the quotation given above, that the aplitic granite is the younger, yet probably intruded during the same diastrophic period.

The aplitic granite outcrops an eighth of a mile northeast of the Barrington railroad station. The same granite cuts micaceous quartzite at the crossing of the railroad and the road north from Villagedale. Between this outcrop and Villagedale, at Solid Rock and also for a mile south of Solid Rock. micaceous quartzite is cut by numerous stringers of aplite,

belonging to this granitic intrusion. The quartzite is highly contorted and the mica is a phase of the exomorphic metamorphism.

In a hand specimen the rock is seen to be a pinkish, very fine-grained granite, minutely porphyritic. The feldspar shows albite twinning in the larger crystals. Mica is distributed unevenly through the rock in small quantities, both muscovite and biotite being present. The quartz lies between the feldspar and is less conspicuous. In thin section the rock is seen to consist of feldspar in hypidiomorphic crystals, a much smaller amount of quartz, rather abundant secondary muscovite, an occasional biotite flake, and some chlorite and titanite. The feldspar is largely a microcline microperthite with smaller amounts of oligoclase. The centers of many of the feldspar crystals are filled with specks of sericite.

The quartz diorite appears to form the remainder of the igneous rock of the area. Outcrops were noted a half mile west of Barrington, at Barrington Passage and to the southward in railroad cuts, and at Shag Harbor. It is a light grey, fine grained rock and shows the effect of shearing, the biotite flakes being orientated into parallelism. Albite-twinned white feldspar and colorless quartz in small amount may be seen in the rock. The grain of the rock is fine, but a few feldspar phenocrysts one-half inch in length may be seen. Under the microscope the constituents are found to be hypidiomorphic crystals of feldspar, a small amount of brecciated quartz showing undulating extinctions, large plates of biotite often clustered in the more brecciated places, accessory titanite in small granular aggregations, quite numerous long rods of apatite occurring in association with the biotite, and a very small amount of iron ore, zircon and muscovite. The feldspar is principally oligoclase twinned after the albite and pericline laws, with smaller amounts of microcline microperthite and albite-oligoclase. The more acid feldspars do not appear in

sufficient abundance for the rock to be called a quartz monzonite.

Rosiwal measurements of the mineral composition by weight of this quartz diorite and of the Shelburne granite are given for comparison:

Barrington quartz diorite		Shelburne granite	
Oligoclase	54.6	Oligoclase	35.2
Albite-oligoclase	.8	Microperthite	3.1
Quartz	21.2	Albite-oligoclase	17.1
Biotite	23.1	Quartz	33.6
Muscovite	.3	Biotite	7.8
		Muscovite	3.1
	100.0	Apatite	.1
			100.0

From these measurements the chemical composition has been calculated:

	Barrington quartz diorite	Shelburne granite
$Si\,O_2$	63.6	72.3
$Al_2\,O_3$	16.8	15.2
$Fe_2\,O_3$	2.0	.6
$Fe\,O$	3.0	1.1
$Mg\,O$	3.1	1.0
$Ca\,O$	3.3	2.5
$Na_2\,O$	4.8	5.0
$K_2\,O$	2.1	1.5
Rest	1.3	.8
	100.0	100.0

The most important characteristic of the granite and quartz diorite is the high soda content. The two rocks are petrographically related, the feldspar being of the same composition and differing only in amounts as do the other constituents.

Dynamic Geology.

The first question which arises in considering the dynamical history of the region is the date of the folding and faulting of the pre-Cambrian sediments. The folding probably took place in pre-Cambrian times, and the faulting in the Devonian diastrophism. The goldbearing series is unconformably overlain by Silurian and by Lower Devonian sediments.

The effect of the folding of the Goldbearing series, was to produce a series of closely folded anticlines and synclines. The axes of these folds are parallel. In Queens County northeast of Shelburne County, the axes trend in a N 45° E to a N 55° E direction, and this direction is characteristic of axes of folds in Lunenburg and Halifax counties to the east. In Yarmouth County, on the west of Shelburne, the trend is N 20°-30° E. In Shelburne County, however, the main axes, according to Dr. Bailey's map, turn toward the Atlantic Ocean in a N 15°-20° E direction. The major axes of the batholiths as shown on the same map, are about N 5° E. In the coastal region considered in this paper, the principal folds are obscured by block faulting*, but the axial direction is N 20° E. It is therefore evident that these axes of mountain-building turn from a S 45° W direction to one of S 20° W, which is toward the Atlantic Ocean and not parallel to the coast line of North America. In "La Face de la Terre" Vol. 1 (fig. 103) Suess and de Margerie plot the tectonic axes of eastern North America, and show the axis of southwestern Nova Scotia turning from a S 65° W direction to one of S 15° E. In view of the above data, it is clear that a turn as great as 80° does not exist. The existing turn is comparable to that of the axis of the Canadian Appalachians into the axis of the Taconic Mountains.

The Goldbearing series throughout Nova Scotia has undergone extensive metamorphism which appears to be entirely

*The faulting is dated, from evidence found elsewhere, as later than the batholithic intrusion, and therefore does not concern the question at hand.

dynamic and contact metamorphism. The former, as shown in Lunenburg and Halifax counties, produced thick-bedded compact quartzite, usually showing minute flakes of mica, and siliceous slates, usually of a grey-green color and very fine grain with no metacrysts. The metamorphism of these beds was not quite completed when the granitic intrusions of Middle Devonian age took place, for the igneous rock is everywhere more or less sheared. The contact metamorphism near the granite has produced recrystallized schist and quartzite, and farther away has caused the formation of metacrystals of staurolite, andalusite, biotite, hornblende, garnet and sillimanite.

In the southern portion of Shelburne County, the contact metamorphism has been so extensive as to be almost regional. On Negro Island, which is 10 miles fron the nearest granite outcrop, the staurolites still persist in the schist although the quartzite is free from metacrysts. The characteristic features of the metamorphism are the development of either staurolite or mica or both in the schist everywhere, the recrystallization of the quartzite near the granite with the development of the muscovite in large quantities and some biotite, and the lack of alteration of the quartzite elsewhere, except near Sand Point where within three miles of the granite some metacrysts appear.

The date of the block faulting, which is shown on the map, is probably late Carboniferous. This diastrophic period did not develop intense folding in the Maritime Provinces, but it was accompanied by faulting. In Kings County the faulting is later than the intrusion of igneous rocks of Devonian age. The details concerning these faults have been sufficiently discussed above. Faults are characteristic of the Goldbearing series throughout its extent, but this block faulting is uncommon in the districts near the gold mines.

Economic Geology.

The most valuable economic resource of the district is granite. West of Shelburne near Hart Point and not over a mile from the Halifax and South-Western Railroad is a granite quarry in bed rock. This quarry has been worked for a number of years, the activity fluctuating with the demand for the product. The granite was loaded on boats within a short distance of the quarry. Also, an extensive quarry business has been carried on in granite boulders here as well as in other parts of the County. At present, granite is being quarried from boulders near the railroad track and transported by rail. The granite appears to split easily and should be very good for building purposes

Ochre is reported at Upper Port LaTour. It occurs on the north side of a hill west of the town. Ochre has also been found a mile and a half south of this town, at the bottom of a well hole 10 feet deep. Neither occurrence was investigated.

Although quartz veins occur in this vicinity, no gold mines have been opened. The saddle reefs of quartz, from which most of the gold is secured in the Halifax district, could not have been formed in a region so highly metamorphosed as the one here considered.

Summary.

The pre-Cambrian Meguma or Goldbearing series was folded into a number of parallel anticlines and synclines and dynamically metamorphosed in the Middle Devonian diastrophism. Granites, quartz diorites and aplitic granites were intruded at this time, being caught in the last of the mountain building movements. These intrusions produced extensive contact metamorphism, staurolite schist being developed ten miles from the nearest granite outcrop. Later, and probably in late Carboniferous time, extensive block faulting took place.

PLATE IV.

A view of Cape Sable Island showing the dissected and downwarped Cretaceous peneplain. This large island is completely covered by glacial deposits, only one bed rock outcrop being found by Dr. L. W. Bailey. A large fire was burning on the island at the time this picture was taken.

The trend of the axes of mountain building, which have determined the outlines of Nova Scotia, turns in Shelburne County from about S 45° W to S 20° W. The axes therefore point away from the land as they dip under the sea, but not at such an angle as given by Suess and de Margerie.

Probably since the end of the pre-Cambrian at least part of the rocks of the Goldbearing series has been exposed to denudation. At the time the ice sheet advanced over the region in the Pleistocene, long valleys had been formed in the Cretaceous peneplain. The land was depressed at about this time to its present level, drowning the ends of the valleys and making the fiords and islands which now characterize the coast line. The action of the ice was to bevel off the rock, but also to leave a thick veneer of sandy ground moraine and boulders over the entire country. Many islands and peninsulas consist, above the present sea level, almost wholly of glacial deposits. Along the depressed shore line the sea is reworking these deposits with the formation of abundant beaches and bars, and in only a few places has the sea cut through the thick veneer and attacked the bed rock.

Coloured Thinking and Allied Conditions.—By D. Fraser Harris, M. D., D. Sc., F. R. S. E., Professor of Physiology in Dalhousie University, Halifax, N. S.

(Read 9 March, 1914.)

There are certain persons in whom sounds are invariably and inevitably associated with colours. Whether these sounds are those of the human voice or the notes of various musical instruments, they are all heard as coloured. This kind of thing is known as coloured hearing; in French, *audition coloreé;* in German, *farbiges Hören.*

The linking together of any two kinds of sensation is called synæsthesia; of all the possible synæsthesiæ, the linking of colour and sound is the commonest. A larger number of persons than might be supposed are the subjects of coloured hearing. As long ago as 1864, the chromatic associations of one of these coloured hearers were described by Benjamin Lumley(2). "I know a person," he wrote, "with whom music and colours are so intimately associated that whenever this person listens to a singer, a colour corresponding to his voice becomes visible to his eyes, the greater the volume of the voice the more distinct is the colour." This person heard Mario's voice as violet, Sims Reeves' as gold-brown, Grisi's as primrose, and so on.

But there is also a small number of persons who, whether they hear in colours or not, always *think* in colours. These persons, called coloured thinkers, do not have any sensation of colour when voices or notes are heard, but they invariably associate some kind of colour with such things as the names of the days of the week, the hours of the day, the months of the year, the vowels, the consonants, etc. This faculty is coloured thinking or chromatic conception and has been called psychochromæsthesia. A typical coloured thinker

who will tell you, for instance, that Sunday is yellow, Wednesday brown, Friday black, may not experience any sensation of colour on hearing the organ played or a song sung. Certain persons are indeed coloured hearers as well as coloured thinkers; but we should distinguish the person who has linked sensations, a synæsthete, from the person whose thoughts are coloured, whose mentation is chromatic, who is, in fact, a psychochromæsthete.

The literature of synæsthesia is much more extensive than any one would be inclined to think who had not made it a special study. Nor is the condition described only in technical publications; there is an increasing tendency to recognize it in current fiction. Thus in "Dorian Grey" we have—"her voice was exquisite, but from the point of view of tone it was absolutely false. It was wrong in colour". Musicians, it would appear, are particularly liable to hear in colours—"The aria in A sharp (Schubert) is of so sunny a warmth and of so delicate a green that it seems to me when I hear it that I breathe the scent of young fir-trees". The musical critic of the "Birmingham Daily Post" thus once complained of a lady's singing; "Her voice should have been luscious like purple grapes". Punch has, of course, not failed to notice this tendency in musical criticism. A writer in the "Daily Telegraph" had thus expressed himself — "To a rather dark coloured, deep, mezzo-soprano voice, the singer joins a splendid temperament"; Punch remarked, "We, ourselves, prefer a plum-coloured voice with blue stripes or else something of a tartan timbre".

Monsieur Peillaube(53), editor of the *Revue Philosphique*, has reported on four persons who have well marked coloured hearing for organ notes, and he calls attention to the numerous cases amongst musicians of definite associations between notes and musical instruments on the one hand, and colours on the other as well as between whole pieces of music and colours. Thus Gounod, endeavouring to express the dif-

ference between the French and Italian languages and giving his preference to the former, used terms relating to colours: "Elle est moins rich de coloris, soit, mais elle est plus variée et plus fins de tintes".

Theoretically, any two sensations may be linked, so that coloured hearing is only one particular variety of synæsthesia (coupled sensations, secondary or dual sensations, secondärempfindungen). No doubt the linking of colour with sound is the commonest of these dual sensations which, following Bleuler[31], might be called sound-photisms. When a taste produces light or colours we have a taste-photism; similarly, there are odour-photisms, touch-photisms, temperature-photisms, and pain-photisms recorded in the annals of abnormal psychology. A good example of pain-photism occurs in a recent novel, "The Dream Ship"[66]. The whole passage is so appropriate to our subject that it may be quoted in full:—"Bran" (a boy) "decided all his likes and dislikes by colour and smell. His favourite colours were yellow, red, green, and wet-black. The last was very different to (*sic*) ordinary black which was the colour of toothache. Little rheumatic pains, which he sometimes got in his knees, were grey. The worst pain you could get was a purply-red one which came when you were sad and gave you the stomach ache. He had once solemnly stated that the only colour he hated was yellow-pink, but as he always called yellow pink and pink yellow, no one had been able to solve the riddle of this hated colour." The black colours of toothache and the grey of rheumatism were this boy's pain-photisms. Something of the reverse order is indicated where a disagreeable colour is described as producing a pain in the stomach. When Baudelaire said that musk reminded him of scarlet and gold, he had an odour-photism.

When the reverse linking occurs, we have an analogous series as follows,—If light or colour produces a sound, it is

a light- or colour-phonism. When a taste is coupled with a sound, we have a taste-phonism and there may exist odour-, touch-, temperature- or pain-phonisms respectively. Sometimes the second sensation linked is of a more vague character, as when screeching sounds produce disagreeable general sensations very difficult to describe. They have been called secondary sensations of general feeling, and they may be akin to those unpleasant sensations evidently experienced by dogs and other animals when they hear music. The late Mr. Grant Allen was evidently alluding to this kind of thing when he wrote in an article on "Scales and Colours," that "Chaos was in dark and gloomy colours, whereas light was treated in white" in such a work as Hadyn's "Creation."

Bleuler[31] believes that phonisms of high pitch are produced by bright lights, well defined outlines, small and pointed forms, whereas phonisms of low pitch are produced by the opposite conditions. An interesting point may be mentioned in connexion with the difference in colour aroused by spoken words and by whispering. Dr. Hélène Stelzner[5] tells us that in her own case full-toned speech appears as a coloured picture, whereas whispering, with its much less resonant vowels, appears like a copper-plate engraving, that is, as non-chromatic.

Quite apart from all these things—synæsthesia—is coloured thinking or chromatic mentation. Here it is not a question of a sensation being present at all, it is that certain persons who have this power, faculty or disability cannot visualize any concept without seeing it in "the mind's eye" as coloured in some way or other. Indeed, the majority of the coloured thinkers questioned by the author do not experience colours when they hear sounds or musical tones, but they cannot think of anything definitely, the month, the day, the hour, without its being thought of as red or yellow or black or white or brown or green or blue. There

is no approach towards unanimity in the colours thought of in association with any one concept or word; for instance, for Saturday the colours selected at random from records in my possession are white, yellow, steel-grey, white-grey, crimson, brown. The coloured thought may be called a psychochrome, and persons who think in colours psychochromæsthetes, the faculty or disposition to think in colours being psychochromæsthesia. Something analogous to this is the case of the blind man alluded to by Locke(1) to whom scarlet was "like the sound of a trumpet."

Apparently the concepts to be most commonly coloured are those for the vowels, the consonants, the months, the days, and the hours of the day. Thus the vowel "a" as in "fame" is mentally coloured in the following five ways in five different persons—red, black, green, white-grey, and white respectively. Or take the vowel "u" as in "usual", we find it psychically coloured as grey-white, yellow, black, brown, blue, and green in six different coloured thinkers. Similarly whole words are associated with colours in the minds of this class of thinkers. One person says he divides all words into two great classes, the dark and the light. Random examples of dark words are man, hill, night, horse, Rome, London, and of light, sea, child, silver, year, day, and Cairo. Or again, another coloured thinker divides up the numerals into those associated with cold colours, grey, black, blue, green; and those with warm, red, yellow, orange, brown, purple, and pink. The odd numbers have the cold colours; the even, the warm. In some cases, as might be expected, the coloured concepts are appropriate or natural as when the word scarlet is scarlet; black, black; and white, white. But an examination of psychochromes shows us that this reasonableness does not necessarily always occur. Thus, the word "apple" is to one coloured thinker a slate grey, which is not the colour of any real apple; and the word "cucumber" to the same person is white; now only the inside of the vegetable itself is white.

Some kind of method, however, may be traced in this chromatic madness, for, according to Bleuler [31] high-pitched notes produce the lighter tints of colour, but low-pitched the darker shades. According to this authority, the colours oftenest aroused in the synæsthesia, sound-photism, are dark brown, dark red, yellow, and white, which is not at all the statement of the frequency of occurrence of colours in coloured thinking. From the records of the psychochromes of two brothers, the relative order of frequency of the colours is white or grey, brown, black, yellow, red, green, and blue; violet and indigo not occurring. Dr. Hélène Stelzner[5] says that green is the colour least commonly thought of. But individual differences are extreme: thus both purple and violet are such favourites with some coloured thinkers that they hardly ever think in terms of any other colours. The present writer[55] has examined the psychochromes of two men, one woman, and one child, with the result that the relative order of frequency of occurrence comes out as white, brown, black, yellow, green, blue, red, pink, cream, orange, and purple. It is thus clear that the colours thought of are not exclusively the pure or spectral ones, for certain non-spectral colours like brown, pink, cream, white, and black are quite commonly reported. The novelist, Ellen Thornycroft Fowler, in a private communication to the author, wrote—"The colour which I always associate with myself, for no earthly reason that I can discover, is blue. Therefore, "E", my initial letter is blue; April, the month of my birthday is blue, and 9, the date of my birthday, is blue." This is known as "colour individuation", and has been made a special study of by Paul Sokolov[47] in his paper "L'individuation colorée" read before the fourth international congress of Psychology held at Paris, 1900. Some people, in short, have their favourite colours, and with these they invest their pleasant thoughts, while their unpleasant thoughts they find coloured by the tints they are not fond of.

Apart, however, from whether certain colours are favourites or not, some few persons have the consciousness of a colour more or less present with them. Thus, R. L. Stevenson had, so he tells us, a feeling of brown which, during his attacks of fever, was unusually distinct. It was "a peculiar shade of brown, something like sealskin".

As might be expected, so acute an observer as Mr. Rudyard Kipling has not failed to notice coloured thinking. In his very curious story "They",(52) he describes the colour concepts experienced by a blind old lady who opens an interview by complaining that certain colours—purple and black—hurt her. Her visitor asks, "And what are the colours at the top of whatever you see?" "I see them so," she replies, "white, green, yellow, red, purple; and when people are very bad, black across the red, as you were just now." The old lady goes on to say that ever since she was quite a child some colours hurt her, and some made her happy. "I only found out afterwards that other people did not see the colours." So unfamiliar is coloured thinking to the ordinary person that a critic wrote (*The Academy and Literature,* October 8th, 1904) "Such tales as 'They' are sheer conundrums." Another writer asked more pertinently, "Are the colours the blind woman described, the colours of different thoughts?"

In Mrs. Felkin's novel, *In subjection* (43) (1900), the heroine, Isabel Seton, is evidently a coloured thinker. Some of her colour associations are given on page 149. The novelist, in a letter to the writer, was good enough to explain that these experiences of her heroine are based on those of an actual prototype, some of whose additional psychochromes she has kindly mentioned. Isabel Seton has synæsthesia also, for the actual sounds of voices call up colours. Thus, soprano voices are to her pale blue or green or yellow or white; contraltos are pink or red or violet; tenors are different shades of brown; while basses are black or dark green or navy blue.

In the novel *Christopher* by Richard Pryce, (61) there is an interesting allusion to a boy who is described as not morbid although he is evidently a synæsthete and a coloured thinker. He talks of playing the sunset on the piano (a colour-phonism), and of smelling moonlight (a light-olfaction). In a novel, *Youth's Encounter,* (64) published in the year 1913 we are told that to one of the characters, "Monday was dull red, Tuesday was cream-coloured, Thursday was dingy purple, Friday was a harsh scarlet, but Wednesday was vivid apple-green, or was it a clear, cool blue?"

It is difficult to express the character of these coloured concepts to persons—and they are the majority of people—who never experience this sort of thing at any time. The colours are not present so vividly as to constitute hallucinations. Coloured visualizings never become hallucinatory, possibly because they are of the nature of thoughts, rather than of subjective sensations. Chromatic conception belongs to the physiology not to the pathology of mind. Coloured thinkers are not continually plagued with phantasmagoria. Mental colourings do not obtrude themselves into one's mental life, they are habitual, natural, chromatic tincturings of one's concepts, and have been so long present to consciousness that they have long ago become part of one's mental belongings. They are invariable and definite without being disturbing.

One coloured thinker has thus expressed himself: "When I think at all definitely about the month of January, the name or word appears to me reddish, whereas April is white, May yellow, the vowel 'i' is always black, the letter 'o' white, and 'w' indigo-blue. Only by a determined effort can I think of 'b' as green or blue, for me it always has been and must be black; to imagine August as anything but white seems to me an impossiblity, an altering of the inherent nature of things." There is thus an inherent definiteness, finality, and constancy about each thinker's psycho-

chromes that is very striking. But it is not alone letters and words that are habitually thought of as coloured, certain coloured thinkers always associate a particular colour with their thoughts about a particular person.

The author of "The Corner of Harley Street"(62) remarks (p. 251) "If only we could use colours now to express our deeper attitude on these occasions, as some of your fellow clergy wear stoles at certain seasons, with what pleasant impunity could we write to one another in yellow or purple or red, leaving black for the editor of the *Times* or the plumber whose bill we are disputing."

"Our alphabet is not rich enough for the notation of the cockney dialect", writes Mr. Richard Whiting in *No. 5 John Street*, "I can but indicate his speech system by a stray word which, if there is anything in the theory of the correspondence between sounds and colours, should have the effect of a stain of London mud." This is evidently an allusion to coloured thinking. There is, unfortunately, no theory at all as yet, but there is the fact of chromatic conception. Quite recently (1913) there was in the "British Review" (65)a vivacious article dealing with coloured thinking from the popular standpoint. The literature that contains the most systematic discussion of coloured thinking is that of the decadent poets of France, the symbolists, as they are called. Some account of their psychochromes is given in Lombroso's "Man of Genius"(30). The eccentric poet, Paul Verlaine, belonged to this school. It evidently includes synæsthetes as well as coloured thinkers for, for them, the organ is black, the harp white, the violin blue, the trumpet red, and the flute yellow. But they think of the vowel "a" as black, "e" as, white, "i" blue, "o" red, and "u" yellow. One of them, Stéphane Mallarmé, has explained in his pamphlet *Traité du Verbe* how these things have come to be.

The following verses—for I hesitate to call them poetry—seem to be an attempt to express the associations of emotions symbolized by the mental colourings of the vowels:

VOYELLES

A noir, E blanc, I rouge, U vert, O bleu, voyelles,
Je dirai quelque jour vos naissances latentes;
A, noir corset velu des mouches éclatantes
Qui bombillent autour des puanteurs cruelles.

Golfes d'ombre, E, candeur des vapeurs et des tentes,
Lances des guerrièrs fiers, rois blancs, frissons d'ombelles,
I, pourpres, sang craché, rire des lèvres belles
Dans la colére ou les ivresses pénitentes.

U, cycles vibrement divins des mers virides,
Paix des pâtis semès d'animaux, paix des rides
Que l'alchemie imprime aux grands fronts studieux.

O, suprème clairon plein de strideurs étranges,
Silence traversée des Mondes et des Anges,
O, l'omega, rayon violet des ses yeux.

J. A. Rimbaud.

We are now perhaps in a position to make some inquiry into the characteristic features of coloured thinking. The first point that strikes one is the very early age at which these associations are fixed. This was a feature recognized by Galton in his classic examination of the subject in 1883(10) The present author's observations fully confirm this point; he has in his possession many letters from coloured thinkers in which the details of their psychochromes differ in the widest possible manner, but all agree in that they testify to the very early age at which the associations were formed. After the publication of the writer's article in the "Scotsman," December 29th, 1908,(59) he received a number of letters spontaneously sent, all emphasising this feature in such

phrases as, "ever since I can remember", "ever since childhood I have always had it", "I do not remember the time when I had not", etc. A writer in "Nature" in 1891,[29] reports on the psychochromes of his daughter when seven years old, at which age she had specifically different colours for the days of the week, namely: blue, pink, brown or grey, brown or grey, white, white, and black. The months of the year were coloured in the following way by a girl of ten who had so thought of them ever since she could remember: brown, olive-green, "art" blue, green-yellow, pink, pale green, pale mauve, orange, orange-brown, grey, grey outlined in black and finally red.

A boy ten years old is reported in the article on Colour Hearing in the "British Review",[65] to have "noticed that the number eight invariably provoked in him the sensation of apricot-yellow, and the number fifteen that of peacock blue". There seems not the slightest doubt that these colour associations are amongst the earliest that are formed in the child mind of the coloured thinker.

The second characteristic of coloured thinking is the unchangeableness of the colour thought of. Middle-aged people will tell you that there has been no alteration in the colours or even in the tints and shades of colour which, for many years, they have associated with their various concepts. Galton remarked on this in his original monograph: "They are very little altered," he said, " by the accidents of education." Galton's phrase was they result from "Nature not nurture". Just as their origination is not due to the influence of the environment, so the environment exercises no modifying influence on them even during a long life.

The third characteristic of psychochromes is the extreme definiteness in the minds of their possessors. Contrary to what might reasonably be expected, the precise colours attached to concepts are by no means vague or incapable of accurate verbal description. A coloured thinker is most

fastidious in the choice of terms to give adequate expression to his chromatic imagery. One of these is not content, for instance, with speaking of September as grey, he must call it steel-grey; another speaks of a dull white, of a silvery white, of "the colour of white watered silk," and so on. One child speaks of March as "art blue," whatever that is; another of 6 p. m. as *pinkish*. The degree of chromatic precision which can be given by coloured thinkers to their visualizing is as extraordinary as any of the other extraordinary things connected with this curious subject.

The fourth characteristic is the complete non-agreement between the various colours attached to the same concept in the minds of coloured thinkers. Thus, nine different persons think of Tuesday in terms of the following colours: brown, purple, dark purple, brown, blue, white, black, pink, and blue. Again, September is thought of as pale yellow, steel-grey, and orange by three different coloured thinkers respectively. Once more, the vowel "i" is thought of as black, red-violet, yellow, white, and red respectively by five persons gifted with chromatic mentation. Unanimity seems hopeless, agreement quite impossible; the colours are essentially individualistic.

The fifth characteristic of psychochromes is their unaccountableness. No coloured thinker seems to be able to say how he came by his associations; "I cannot account for them in any way" is the invariable remark one finds in letters from persons describing their coloured thoughts.

The sixth characteristic is the hereditary or at least inborn nature of the condition. Galton's phrase was "very hereditary". The extremely early age at which coloured thinking reveals itself would of itself indicate that the tendency was either hereditary or congenital. The details of a case of heredity from father to son have been reported for coloured hearing by Lauret and Duchassoy; a case of coloured thinking reported by the present writer was one

of heredity also from father to son. But these related coloured hearers did not see the same colours for the same sound, nor did the two coloured thinkers think in the same colours. From the writer's inquiries, coloured thinking is certainly congenital even when it cannot be proved to be hereditary. This point will come up again in connexion with the origin of the condition, but we may at present note that those who have studied the subject are unanimous in denying that at any rate coloured thinking is due to environmental influences.

It may be now asked what manner of people are they who are coloured hearers or coloured thinkers or both. The late Mr. Galton told us that they are rather above than below the average intelligence. The writer's observation would, in the main, confirm this; they are at least invariably well educated persons who confess to being coloured thinkers. In his book, Mr. Galton gave a few names of distinguished persons of his acquaintance, and his list might be brought up to date by the addition of some names quite as distinguished. But all persons who have coloured hearing or coloured thinking are not necessarily distinguished—a large number, as we have seen, are yet children—but they are all probably more or less sensitive. Possibly they are more given to introspection than is the ordinary person. At any rate, what is quite certain is that both synæsthetes and psychochromæsthetes belong to the group of strong visuals or "seers" as Galton called them. Seers are persons who visualize or exteriorize their concepts either as uncoloured forms or as coloured in some way or other. The uncoloured thought-forms are very curious, some of which Galton gave as examples in the appendix to his work. One distinguished neurologist always sees the numerals 1 to 100 in the form of a ladder sloping upwards from left to right into the sky. As this concept is not coloured, it cannot be called a psychochrome, but it might be called a psychogram. A psychogram is,

then, the uncoloured thought-form of a concept, and people who have psychograms must be strong visualizers.

The school of symbolist poets in France to which Ghil, Malarmé, Rimbaud, and Verlaine belong, appears to lay a great deal of stress on the so-called meaning of colours. The school evidently includes both coloured hearers and coloured thinkers; but, whereas, the majority of coloured thinkers derive no particular meaning from their psychochromes, the symbolists attach considerable significance to the colours which happen to be associated with their thoughts. The different vowels, for instance, mean to them or represent for them particular emotions or states of mind not in virtue of the sound of the vowel but entirely through the related colour. The particular emotion symbolized by any given colour seems to the ordinary person rather arbitrary if we judge by the details in Rimbaud's poem; but we are aware that there has always been a tendency to represent emotional states in terms of the language of colour. Homer spoke of "black pains"; we constantly speak of a black outlook, a black lie, a white lie, a black record, a grey life, a colourless life, and so on. There is, in fact, growing up in England a school of musicians who hold that it should be possible and pleasurable to represent music chromatically. Whether the general public will ever enjoy silent music seems very doubtful, but it is notorious that most people derive a great deal of pleasure from the display of coloured lights, illuminated vapours, coloured steam, "fairy fountains", Bengal lights, a house on fire, and similar exhibitions in the open air. People undoubtedly do like to see great surfaces or masses vividly coloured as in the rainbow, the sunrise or sunset, the afterglow on snowy mountains, the streamers of the northern lights, and so forth. But whether they would care to have audible music suppressed and to have offered them a succession of coloured surfaces or patches of colour even following one another in the se-

quence or rythm required by music, is open to serious question. Such, however, is the intention of Mr. A. W. Rimington, as explained in his book, "Colour in Music",(63) in which there is much that is true and interesting. "It is undeniable," he writes, "that as a nation our colour sense is practically dormant . . . Compare our colour sense with that possessed by the Japanese, the Indians, or even the Bulgarians and Spaniards. . . To my mind, a wide-spread, refined colour-sense is more important than a musical one." Long before Mr. Rimington's work was published, there appeared a little book privately printed at Leith in Scotland called "Chromography or tone-colour music"(23). The author assigned a colour to each of the notes of the scale thus— do = red, re = orange; mi = yellow; fa = green; sol = blue; la = violet-purple; ti = red-purple.

Many persons have synæsthesia in connexion with musical tones (sound-photisms); two cases reported by Albertoni(24) associated blue with the sound of Do (C); yellow with Mi (E); and red with Sol (G). But it was discovered that they were colour-blind for red (Daltonism). Now, whereas, they could recognize and name the other notes, they could not name G, a disability which Albertoni thinks was related to the Daltonism; he has accordingly called it Auditory Daltonism ((Daltonismus auditivus), a psychical deafness depending on the red-blindness since the note to which they were psychically deaf was the one which called up mentally the particular colour, red, to which they were actually blind.

It might be now asked whether we have any explanation of the causes or causal conditions of coloured thinking; why may thoughts be coloured at all; and why should particular thoughts come to be associated with particular colours? Why should only a few persons, about 12 per cent. in fact, be found to be coloured thinkers? The answers, if answers they can be called, are disappointing in the extreme,

for we have no satisfactory explanations of any of these matters. The very arbitrariness of the associations defies theoretical analysis.

If it is the function of science merely to describe, then our work is done; but in a subject such as this, to make no attempt to account for the abstruse phenomena observed would be a distinctly feeble conclusion of our studies. It has been suggested that the case of coloured thinking is no more recondite than the influence of some picture-book or paint-box, which in early life determined for us ever afterwards the colours of certain concepts. Now, though many people do regard their coloured thinking as a childish survival, the picture-books will account for very few of the best established psychochromes. In some few cases, environmental influences do seem to have been casual. Thus, in one case known to the writer, the colour of February as white was accounted for by the influence of the surroundings. The earliest February remembered was snowy, and through the whiteness of the snow the concept of February came to be and ever afterwards remained white. But it is clear that if environmental influences are operative in anything like a large number of cases, the colours for such concepts as the months of the year ought to be far more uniform than they are. No common origin of external source can make one person think of August as white, another as brown and yet another as crimson. If August is white to one person because it is the month of white harvest, then it ought to be white to all persons capable of receiving any impressions as to the colours of harvest. But to the vast majority of people it is perfectly absurd to talk of August having any colour at all; and to the few who think it coloured, it has not by any means the same colour; all seems confusion.

Monsieur Peillaube(54) has made a suggestion of a different kind as likely to explain some of these colour associations.

Monsieur Peillaube became acquainted with a Monsieur Ch—— who had audition colorée as well as colored thinking. Monsieur Ch—— had an excellent memory and was able to submit his conceptions to searching introspection with the result that he seems to have discovered what may be called the missing link in the associational chain of mental chromatic events. To this coloured thinker the lower notes of the organ were of a violet colour. This seems to have been brought about in the following way: low notes of any kind were sweet and deep (douces et profondes), the colour violet is sweet and deep, therefore it came to pass that the low notes were associated with violet. Similarly, to Monsieur Ch—— the vowel sound of "i" was suggestive of something "vive et gaie," the colour green had always been associated with liveliness and gaiety, therefore he thought the vowel "i" was green. These conclusions were reached only after considerable introspection, for it must be understood that the link between the low notes and the colour violet was by no means an explicit or definite presentation in this person's mind, at the time that Monsieur Peillaube suggested the enquiry. Peillaube's theory, then, is, that these apparently arbitrary and instantaneous linkings of sounds (x) to colours (y) or of thoughts to colours, are really, after all, cases of association of two terms through the intermediation of a third factor an emotional link (l) now subconscious but revivable. The sequence was x-l-y, but in course of time the "l" had dropped out of consciousness leaving the "x" and the "y" apparently indissolubly joined together.

Finally it may be asked, would the capability of coloured thinking cause its possessor to be classed as mentally abnormal. The answer is in the negative. Coloured thinkers may not conform to the usual or most commonly met with mental type, but they deviate from that type only in the same way that geniuses deviate from it. Inasmuch as they

deviate from the normal, coloured thinkers are, of course, abnormal, but there is nothing in them allied to instability of mental balance. Some coloured thinkers may, no doubt, belong to families in which some degree of mental instability is present, or, on the other hand, some relatives of coloured thinkers may possess a high degree of artistic or musical ability, of scientific or philosophical insight, that quality in fact, of genius so exceedingly difficult to define. Genius is something notoriously not conferred by training or education, if not inborn it cannot be acquired; exactly the same may be said of coloured thinking. Our studies have at least shown us this, that it is not in the ordinary type of mental constitution but in the recesses of the slightly supernormal that this recondite problem of psychology presents itself for analysis and explanation.

Appendix

Being the psychochromes in an actual case.

a.—blue-white (like a dead tadpole).
b.—dark brown-red.
c.—brighter red.
d.—pea-green.
e.—fawn-yellow.
f.—a yellow, brighter than e.
g.—dark brown, nearly black.
h.—black.
i.—chocolate brown.
j.—a dull red (not the same shade as the other reds).
k.—bright brick-red.
l.—black.
m.—bright yellow.
n.—dark brown (nearly black).
o.—white.
p.—white with just a tinge of blue.
q.—pale blue-green.
r.—black (nearer to h than to l).

s.—white.
t.—mustard colour (ugly).
u.—brown-yellow.
v.—olive green.
w.—red (like c).
x.—green.
y.—an ugly yellow.
z.—very bright scarlet.

Sunday.—red.
Monday.—pea-green.
Tuesday.—fawn yellow.
Wednesday.—black.
Thursday.—fawn (not as bright as Tuesday).
Friday.—green (a very ugly bile colour).
Saturday.—white.

January.—dull red.
February.—fawn.
March.—a green mustard colour.
April.—blue white.
May.—sunshine colour
June.—dull red.
July.—a slightly darker red.
August.—olive green (more yellow than n).
September.—white.
October.—green.
November.—black brown.
December.—a blue shot with green.
Christmas.—white.
Whitsun.—nearly a rose pink.
Easter.—black with something white in the middle.

One.—black.
Two.—blue-white.
Three.—fawn.

Four.—dark red.
Five.—white.
Six.—bright yellow.
Seven.—black.
Eight.—white.
Nine.—green.
Ten.—mustard-green.
Eleven.—brown-yellow-green.
Twelve.—pale brown.

BIBLIOGRAPHY.

1. 1690 Locke, John; Philosophical Works; Bohn, London, 1868; Vol. II, p. 26.

2. 1864 Lumley, B.; Reminiscences of the Opera; London, 1864, pp. 98-99.

3. 1873 Bruhl, Wien. med. Wochenschr, nos. 1-3.

4. 1879 Lewes, G. H.; Problems of Life and Mind; Third Series, London 1879.

5. 1880 Galton, F.; Nature, London; 1880, Vol. XXI., p. 252.

6. 1880 Galton, F.; Ibid, p. 494.

7. 1881 Bleuler, E. und Lehmann, K.; Zwangmässige Lichtempfindungen durch Schall und verwandte Erscheinungen; Leipzig, 1881.

8. 1881 Steinbrügge; Ueber secondäre Sinnesempfindungen; Wiesbaden, 1881.

9. 1882 Mayerhausen; Uber Association der Klänge speciell der Worte mit Farben; Klin. Monatsbl. f. Augenheilk, 1882.

10. 1883 Galton, F.; Inquiries into human faculty and its development; Macmillan, London 1883, p. 145-177.

11. 1883 Lussana; Sur l'audition colorée; Arch. Ital. de Biol. 88.

12. 1883 Pedrono; De l'audition colorée: Annal d'Oculiste, 1883.

13. 1883 Schenkl; Ueber Association der Worte mit Farben; Prager Medic. Wochenschr, 1883.

14. 1884 Hilbert; Klin. Monatsbl. f. Augenheilk.

15. 1885 DeRochas A.; Audition colorée; La Nature, April, May, September, 1885.

16. 1885 Girandeau; De l'audition colorée; L'Encephale, No. 5, p. 589, 1885.

17. 1887 Baratoux; Audition colorée; Progrès Medicale, 1887.

18. 1887 Feré, C.; La vision colorée et l'equivalence des excitations sensorielles; Soc. de Biol.,Paris, 1887.

19. 1887 Pick; Mendel's Neurolg, Centralbl, p. 536, 1887.

20. 1887 Urbantschitsch; Sitzungsbericht d Gesellsch; d. Aertze in Wien, October 1, 1887.

21. 1887 Ditto; Münch. med. Woch, October 25, 1887, p. 845.

22. 1888 Lauret et Duchassoy; Bull. Soc. de psychol. physiol; Paris, Tome III, p. 11; Abstract in Centralbl, fur Physiol, Leipzig und Wien, 1888, s. 125.

23. 1888 Watt, William; Chromography or tone-colour music; Leith, 1888.

24. 1889 Albertoni; (abstract) Centralbl. f. Physiol., Leipzig und Wien, 1889, s. 345.

25. 1889 Kaiser; Association der Worte mit Farben; Arch. f. Augenheilk, 1889.

26. 1889 Raymond, P.; Une observation d'audition colorée; Gzette des Hopitaux, 1889.

27. 1890 De Mendoza, Suarez; L'audition colorée; Paris, 1890.

28. 1891 Delstauch; Une observation d'audition colorée; Annal des maladies de l'oreille, 1891.

28. 1891 Holden; Nature; London, 1891, Vol. XLIV, p. 223.

30. 1891 Lombroso; The man of genius; London, W. Scott, 1891, p. 231.

31. 1892 Bleuler; Article, Secondary sensations (pseudochromæsthesia) Dict. psych. med.; Edited by Tuke, London, Churchill, 1892.

32. 1892 Calkins, Mary W.; Amer. Jrl. Psych.; Vol. V., no. 2, Nov. 1892.

33. 1892 Grüber; L'audition colorée; Proc. Intern. Cong. Exper. Psych., London, 1892.

34. 1892 Krohn; Pseudochromæsthesia; Amer. Jrl. Psych., Oct. 1892.

35. 1893 Calkins, Mary W.; Statistical Study of pseudochromæsthesia and of mental forms; Amer. Jrl. Psych., July, 1893.

36. 1895 Mirto, G.; Contributo al Fenomeno di Sinestesia visuale, Palermo, 1895.

37. 1895 Robertson, W. J.; A century of French verse, London, 1895. (For transaltion of Arthur Rimbaud's poem "Les Voyelles".)

38. 1897 Zehender; Ein Fall von Geschmaksphotismus; Klin. Monatsbl., f. Augenheilk, 1897.

39. 1899 Symons, A.; The symbolist movement in literature, 1899.

40. 1899 Claviere, J.; L'audition colorée; Ann. Psychol., Vol. V, 1899, p. 161-178.

41. 1899 Ditto; Ann. de Soc. Psych., Vol. IX, p. 257-271, 1899.

42. 1900 Daubresse; Audition Colorée, Rev. Philosoph, 1900.

43. 1900 Fowler, E. T.; In Subjection, London, Hutchinson, 1900, p. 149.

44. 1901 Laigneland Lavastine; Audition colorée familiale, Rev. Neurolog., 1901.

45. 1901 Lemaitre; Audition colorée et phenomènes connexes observés chez des écoliers, Genève, 1901.

46. 1901 Sokolov, P.; L'Individuation colorée, Rev. Philosoph, 1901.

47. 1901 Sokolov, P.; L'individuation colorée, Trans. IV Cong. intern. de psychol. tenu à Paris, 1900, Paris, 1901, pp. 189-193.

48. 1902 Romby; L'Hysterie de Ste Thérèse, Arch. de Neurol, Vol. 14, 1902.

49. 1903 Dressler; L'audition colorée, evolue-t-elle, L'Année biol., Vol. VIII, 1903, p. 406.

50. 1903 Lemaitre; Cas d'audition colorée hallucinatoire, cas héréditaire, L'Année Biol. Vol. VIII, 1903, p. 421.

51. 1903 Stelzner, Hélène; Fall von akustisch-optischer Synæsthesie, Græfe's Arch. Ophth., Leipzig, Vol. 55, 1903, p. 549-563.

52. 1904 Kipling, R.; Traffics and Discoveries, London, 1904.

53. 1904 Peillaube; Rev. Phil., Paris, 1904, Nov., p. 675.

54. 1904 Peillaube; Communication to the VI International Congress of Physiology, Brussels, Setpember, 1904.

55. 1905 Harris, D. Fraser; Psychochromæsthesia and certain synæthesiæ. Edin. Med. Jourl., Dec. 1905.

56. 1905 Lomer, G.; Farbiges Hören (Auditio Colorata) Arch. f. Psychiat., Berlin, 1905, Vol. 40, p. 593-601.

57. 1905 Colville, W. J.; The human aura and the significance of colour, London, 1905.

58. 1908 Harris, D. Fraser; Coloured Thinking, Jrl. Abn. Psychol., Boston, June-July, 1908, p. 97.

59. 1908 Ibid; Coloured Thinking, Scotsman, December 29, 1908.

60. 1908 Ibid; Coloured Thinking, Rev. Neurol. and Psych. Edin. September, 1908.

61. 1911 Price, R.; Christopher, London, Hutchinson & Co., 1911, p. 81.

62. 1911 The Corner of Harley Street, London, Constable, 1911, p. 251.
63. 1912 Rimington, A. W.; Colour in Music, London, 1912,
64. 1913 MacKenzie, C.; Youth's Encounter Toronto, Bell & Cockburn, 1913.
65. 1913 Martindale, C. C.; Colour hearing, British Review April 1913, Vol. II, No. 1.
66. 1913 Stockley, C.; The Dream Ship, London, Constable & Co., 1913, p. 229.

Analyses of Nova Scotian Soils.—By Prof. L. C. Harlow, B. Sc., B. S. A., Provincial Normal College, Truro, N. S.

(Read 20 April 1914)

"The soil is so complex in its relation to crops that it has been and still is one of Nature's greatest puzzles." What intricate actions, physical and chemical, are those which take place when the rain descends upon, or the salt tide water spreads over the marsh lands of our Province! Pages are written upon the action between two substances in a test tube; it is only natural then that much is afforded for investigation in one of Nature's great test tubes, the Bay of Fundy, where the fine residues carried by streams from the various geological formations are mechanically stirred by the ceaseless tide.

An analysis of the ebb tide water at the mouth of the Shubenacadie shows .622 grams of silt suspended in every 1000cc of water. Now this silt is the result of the breaking down, the weathering and transportation of the rocks of the Province. Of what is it composed mineralogically and chemically? A number of investigators as Delagé, Bonsteel and Ries, who have labored to determine the minerals in the soil have come to the conclusion that it has all the minerals unaltered which are present in the rocks. The commonest are quartz, limonite, hematite, kaolin, feldspar, micas, apatite, hornblendes, pyroxenes, chlorite, tourmaline, rutile, calcite, dolomite, selenite, zeolites.

Again the rocks as sandstone, shales, limestones, of one group, have the same mineral constituents as the granites, gneisses and schists of another group; but differ first, in the varying proportion of these minerals, and secondly in that the first group are water formed, the second heat formed.

Hence, a soil, whether artifically made by powdering a rock, or taken from a lately deposited marsh area, from a leached hillside or from a field worn out by cropping, will give the essential elements as shown by the analysis of the following:

	A. New tide deposit from Gaspereau River	B. A "worn out" hillside field from Upper Stewiacke, Col. Co.
Insoluble in acid of 1.11 sp. gr.	83.66	80.02
Potash	.72	.42
Soda (Na_2O)	.82	.09
Lime	.9	.55
Magnesia	1.39	.63
Sulphuric acid	.19	.11
Ferric oxide } Alumina }	7.7	3.25
Alumina		5.68
Phosphoric acid	.1	.12
Volatile at red heat	3.57	8.51
Water at 100°	1.1	1.28
Nitrogen	.06	1.8

Further analysis of the same ebb tide water shows in 1000cc 29.95gm. of dissolved solid made up as follows:—

Sodium chloride	24.24
Potassium chloride	.38
Magnesium chloride	2.47
Magnesium bromide	.036
Magnesium sulphate	1.63
Calcium sulphate	1.18

In addition to these, Ditmar gives about 30 other elements which are easily proven in salt water. That rock residue may become available to plants has been proven by Wöhler, who, in a classical experiment, found the zeolite apophyllite to be sufficiently physically soluble in pure water to be recrystallized from it. F. W. Clarke found muscovite, orthoclase, albite, and othei micas, feldspars and zeolites to be soluble in pure water.

Again, Lemberg found that leucite, $KAlSi_2O_6$ in NaCs 10% solution gave $NaAlSi_2O_6$ and KCl; also that feldspar with ordinary soluble salts gave similar exchange of basic elements. These are the changes which must be taking place in our Bay of Fundy waters, and of which Cameron of the U. S. Bureau of Soils says "It is to be regretted that there are not more precise data available as to the stability of the various rock forming mineral species in contact with solutions of the more common and readily soluble salts at ordinary temperatures since such data would be of great value for geological, mineralogical and soil studies."

If the tide water with its dissolved matter acting on the newly brought down rock debris presents a wide range of possible new substances, how much more complex will be the action in a field, marsh or upland where we have organic matter, more or less decomposed; soil atmosphere, living plant organisms as bacteria, molds, ferments; animal forms as protozoa, in addition to the rock residues bathed in the soil moisture which is a solution of products yielded by many components and in equilibrium or nearly so with the solids or gases with which it is in contact.

Scientific Agriculture is the handling of this heterogeneous mixture so as to give, with a minimum of labor, the greatest crop return, and yet be able to pass it over to the next generation, not in an exhausted condition, but permanently improved. It is based on knowledge which is far from complete. Our marsh soils in some places are "run out," giving one half ton of hay per acre. Why is this? We usually say that the available plant food is used up; on the other hand the Bureau of Soils at Washington has, within the last ten years, advanced the Toxin theory which is, that plants in exhausted soils are like human beings in a room, the air of which is polluted by excreted substances, disagreeable and sickening; that the growing plant excretes poisons which, if allowed to accumulate in the soil, kill the plant;

that fertilizers by chemical action destroy these poisons, rendering the soil healthful for growing plants.

Some of these toxins, as picoline carboxylic acid, dihydroxystearic acid and agroceric acid, have been isolated from the soil and their deleterious effects shown on seedlings. These two views have led to a long discussion between the soil men at Washington and another group represented by Hall, of England, and Hopkins, of Illinois. One writer says "The practice of Agriculture has suffered and is suffering today from an insufficient accumulation of facts and data and from an overproduction of theories and conclusions".

It is the purpose of this work to provide some data regarding the *ultimate* composition of the rock debris found in the soils of this Province. To this end 125 samples of soil have been collected, 86 of which have been studied with particular emphasis on the chemical analyses and the relationship of the soil to the surrounding rock, both native and drift. This work has been my pastime during vacation seasons since 1908.

Samples were taken as follows:—

24 Marsh soils from various points between Kingsport and Windsor, along the Cobequid Bay and from the Amherst areas.

25 at various places along a line extending across the county from Tatamagouche to Middle Musquodoboit.

12 from the central part of Lunenburg county.
8 from the Annapolis valley.
10 from the Wentworth valley.
2 from the Government farm, Truro.
2 near Antigonish town.
1 from Guysboro county.
1 from Digby county.
1 from Clifton, Colchester county.

This article will present results of the analyses with tentative deductions therefrom. It is expected that this work will be continued so as to include soils from all parts of the Province and special study of certain problems which at present can only be suggested.

While *good* soils differ in the amounts of the essential elements, yet the following standard from Professor Snyder, Minnesota Exp. Station might be taken for comparison:—

Potash soluble in acid	Phosphoric acid	Lime	Nitrogen
Good soil........ .3-.6%	.15% if neutral or alkaline.	.3 to .5% if partly limestone	.2%
Poor soil......... ·1%	.05%		.07%

The following table gives the composition of typical soils from various geological areas of the Province.

TABLE I.

Constituent		Ign.	Sil.	Permian.		Carboniferous					Triassic			Cambrian	
	A	5	6	1	2	3	4	5a	7	8	9	10	11	13	12
Insoluble........	79 95	76.14	76 48	85.92	87.44	86.31	89.00	82.78	72.93	78.04	87.18	81.64	81.45	76.73	73.78
Potash..........	.29	.12	.36	.15	.11	.12	.13	.3	.5	39	.26	.31	.41	.15	.3
Soda	25	.03	.06	05	.09	.11	.08	.05	.04	.1	.4	.06	.01	.16	.3
Lime	2.16	.38	.3	.3	.3	.29	.4	.17	.5	.27	.25	.3	.2	.3	.35
Magnesia	.55	.23	.42	.41	.72	.29	.52	.92	.49	.23	.28	.7	.83	.74	.38
Sulphuric acid ..	.03	.18	.05	.08	.07	.07	.05	.11	.09	.08	.14	.07	.04	.08	
Iron oxide	2.68	3.15	3.28	2 65	2.80	3.10	3.40	3.63	3.05	3 45	2.74	3.40	2.90	9.1	2.5
Alumina........	5.20	3.74	4.14	2.72	2.72	2.80	2.75	3.89	5.88	5.73	2.22	4.33	3.28		3.75
Phos. acid	.23	.11	.08	.08	09	.15	.05	.18	.29	.19	.09	.22	.12	.002	.27
Volatile or organic	7.00	12 36	11.88	7.26	4.65	5.01	2.88	7.61	11 66	9.58	5.35	10.28	6.22	11.12	10.85
Moisture........		3.49	2.76	1.17	1.13	1.51	.76	.94	4.46	2.06	1.2		3.98	2.37	6.65
Nitrogen........	.29	.34	.18	.15	.08	.1	.02	.18	24	.23	.14	.17	.1	.21	.34

EXPLANATION OF TABLE I.

A.—Average of 200 United States fertile surface soils. Snyder, Minnesota Exp. station.

No. 5—From the head of Wentworth valley, Cumberland county, would be made up of debris from the igneous rock of the Cobequids; organic matter is due to the field being used as pasture for a long time.

No. 5—The Silurian rock area in Nova Scotia is small; this sample from near Wentworth Station is a mixture of decayed igneous rock, Silurian sandstone and Drift.

Nos. 1 and 2—are typical of the large Permian areas north of the Cobequids. No. 1 is a very productive hay field. No. 2 is virgin soil.

No. 3—is a fairly productive soil from Wentworth Center, Millstone Grit area.

No. 4—is a subsoil from a model orchard at Aspen, Guysboro county.

No. 5a—is an average of 5 soils from the Limestone areas Stewiacke and Musquodobit valleys.

No. 7—is a well cultivated and productive field at Antigonish on the Carboniferous limestone.

No. 8—is from the same geological formation at Wentworth, Cumberland county.

No. 9 is a surface virgin soil from Government farm, Truro.

No. 10—is an upland soil on the Midland railway about eight miles from Truro.

No. 11—From Atlanta, Kings county; an orchard soil.

No. 12—A surface, virgin soil from central Lunenburg.

No. 13—A soil from Hectanooga, Digby county, farm of Father Broque.

TABLE 2—MARSH SOILS.

	1	2	4	q	u	A	G	C	E	F	M	14	H	S	t	13
Insoluble..	84.91	76.77	84.76	82.70	83.66	83.02	77.04	74.92	78.44	78.07	76.24	83.04	75.6	77.23	78.33	75.31
Potash....	.58	.98	.61	.79	.72	.64	.61	1.22	.84	.63	.48	.27	.75	.62	.99	03
Soda.....	.48	.53	.78	.64	.82	1.49	1.43	1.24	1.46	.76	88	.57	1.14	1.08	.36	02
Lime	1.05	.7	1.15	.65	.9	1.05	.83	.67	.4	.6	.6	.6	.3	.3	.65	.4
Magnesia	1.40	2.04	.97	1.23	1.39	1.13	.65	.85	.58	.86	78	.13	.4	1.65	1.58	1.17
Sulphuric acid....	.14	.25	.28	.12	.19	.31	.75	.55	.85	.79	.96	.17	.8	.11	.09	.61
Iron oxide	7.3	12.2	7.5	9.2	7.7	3.54	5.63	5.45	6.35	8.0	4.5	2.90	5.3	13.1	11.2	4.1
Alumina						3.74	5.45	6.09	4.35	3.44	6.9	4.54	5 4			5.5
Phosphoric acid....	.13	0.18	.05	18.	.1	.18	.27	.34	.21	.21	.19	.21	.25	.16	.16	.19
Volatile or organic	4.22	5.02	3.32	4.29	3.57	3.00	5.00	6.92	4.77	6 01	5.75	4.89	8.12	3.98	5.75	10.43
Moisture .	.27	1.82	.82	1.24	1.1	.71	2.1	.43	1.55	1.5	2 62	1.89	2 12	1.6	1.43	1.86
Nitrogen..	.05	.15	.06	.08	.06	.14	.36	.27	.26	.29	.24	.13	.35	.05	.14	.26

EXPLANATION OF TABLE II.

New Deposits of Marsh Mud.

No. 1—from Mr. Carl Church's property, Falmouth.

No. 2—from Mr. C. H. Black's property, Amherst.

No. 4—from Cornwallis River, near Wolfville.

No. q—from Mr. Taggart's farm, Masstown, Colchester county.

No. u—from Gaspereau River, Mr. Patterson's land.

No. A—from Mr. A. C. Layton's property, Great Village.

No. G—from Folly River, Colchester county.

No. C—from Mr. Urquhart's property, Folly; dyked 3 years before and salt marsh grasses being crowded out by timothy, etc.

No. S—taken at depth of 27-36 inches from A. C. Layton's new marsh, Great Village.

Good Dyked Soil.

No. H—Great Village; cropped for ten years with no treatment; at the time of sampling gave 2½ tons hay per acre.

No. t—from same property, ploughed two years before and gave in 1907, four tons hay per acre.

Run out Marsh.

No. E—Old marsh of Mr. Morrison, Folly, Colchester county.

No. F—Old marsh of Mr. Urquhart, Folly, Colchester county, full of weeds.

No. M—Very sour soil: full of weeds: no drainage: Mr. C. T. Smith, Folly.

No. 13—Mr. Patterson's, Horton, Kings county.

No. 14—Mr. C. Logan, Amherst Point: ½ ton hay to the acre.

TABLE 3—SOILS FROM TATAMAGOUCHE AND STEWIACKE.

	22s	16s	6s	11s	17s	7n	13n	2n	12n	9n
Insoluble	85.59	79.56	83.19	80.02	79.33	91.13	85.12	72 15	86.08	65.14
Potash	.28	32	.36	.42	.4	.19	.21	.39	.29	.55
Soda	.05	.05	.15	09	.08	.06	.13	.27	.15	.48
Lime	.20	.12	.20	55	.33	.10	.39	.35	.42	.55
Magnesia	1.21	.71	.73	.63	1.0	.37	.66	1 15	.52	.57
Sulphuric Acid	.09	.12	.11	.11	.07	.16	.10	.13	.10	4 32
Iron oxide	2.54	4.61	3.74	3.25	4.15	1.30	2.25	4.45	2.22	8.32
Alumina	3.92	4.85	2.91	5.68	6.66	2.11	2.27	7.64	2.94	.16
Phosphoric acid	.14	.19	.20	.12	.14	.09	.18	.31	.14	.15
Organic	6.54	8.3	8.19	8.51	8.12	4.08	7.96	11.3	6.54	15.6
Moisture	.44	1.24	1.25	1.28	1.74	.71	1.21	2.16	1.41	3.35
Nitrogen	.13	.21	.22	.18	.17	.07	.23	.3	.15	.83
Humus	1 30	2.55	2.75	2.7	2.56	1.65	2.70	3.30	1.85	.....

EXPLANATION OF TABLE III.

No. 22s—From worn out hillside, Campbell Brothers, Stewiacke.

No. 16s—Mr. D. W. Reid, Middle Musquodobit; model orchard giving good returns for 25 years; mostly barn manure.

No. 6s—Property of Dr. Reynolds, Otter brook, Stewiacke; old field near river intervale.

No. 11s—Worn out hillside at Mr. E. Hamilton's, Springside, Colchester county.

No. 17s—Middle Musquodobit; the Layton farm, giving fair hay crop with no cultivation.

No. 7n—Pasture, newly broken up and given little bone meal. Mr. J. Cunningham, Bayhead, Colchester county.

No. 13n—Turnip field giving good yield; previously in hay for several years; 40 tons barn manure per acre. Mr. A. P Semple, Brule.

No. 12n—Mr. Jas. Kennedy, Brule; upland not ploughed for 8 years; top dressed once with barn yard manure; yield 2 tons per acre.

No. 2n—McCallum's Settlement; old field.

No. 9n—Run out upland; farm of Wm. Charlton, Stake Road, Cumberland county.

Averaging up these analyses we have:—

TABLE IV.

	Acid Sol. Potash	P_2O_5	Lime	Org.	Nitrogen
16 Marsh soils	.75	.15	.75	6.7	.18
10 Upland	.34	.16	.3	10.	.25
14 of Table I	.2	.14	.25	10.3	.17
Average of 200 fertile surface American soils—*Snyder*	.29	.24	2.16	7.	.29

What is the availability of the plant food in Nova Scotia soils? Four samples collected by the writer and analyzed at Ottawa under the direction of Professor Shutt gave as follows:

	Lime		Potash		Phosphoric acid	
	Acid soluble	Available	Acid soluble	Available	Acid soluble	Available
1—Good soil	1.64	.99	.27	.048	.23	.087
2—Virgin soil	.04	0	.145	.105	.026	.011
3— "	.36	.15	.37	.019	.11	.023
4— "	.11	.02	.42	.018	064	.023

Of the important plant foods nitrogen, lime, phosphoric acid, and potash, consider first potash. We regard it as existing in the soil in the easily soluble or available form; the more difficult soluble or acid soluble and the insoluble part; for example a soil analyzed:

POTASH

Insoluble in acid...............	.737%	.886 % unavailable
Acid soluble....................	.149%	
Available.......................	.02 %	

That is, there are 45 times as much insoluble potash as available.

Dyer, in Proc. Royal Society, 1901, says that less than .01 to .03 per cent of available phosphoric acid in a soil indicates the need of phosphate manures and that soils with .01 per cent of available potash probably require no application of potash manures.

Hence, from Dyer's statement and the analyses in Tables 1-5 we can say that our soils have a good supply of potash but available to a limited extent. Comparing soil No. 1, which has a good supply of lime and organic matter, with Nos. 2, 3, and 4, low in these components, one may account for the greater proportion of available potash in No. 1.

Phosphoric Acid.

The total phosphoric acid of the soil exists in a much more easily soluble form than the total potash; the acid soluble phosphoric acid is the total and is found in our soils as shown in the summary, Table 4. The phosphoric acid is, as shown in Table 5, about one-fourth available and therefore soon used either by the plant, or washed away as a sediment.

Lime and Acid Soils.

Comparing the percentage of the important constituents with standards given, one notices the deficiency of lime. The lime, CaO, shown in the hydrochloric acid extract may come from dissolving the limestone or the lime silicates; since limestone cannot exist in the presence of acids we are led to test soils for acidity.

Acid Soils.

A simple test for an acid soil is: Place a lump of damp soil on a piece of moistened blue litmus; a reddening shows the presence of acid. Out of sixty-eight soils from upland, intervale, and marsh so tested, only ten showed no acid reaction and of these, six were new marsh deposits; the four only, cultivated soils showing no acid reaction were from areas giving good crops, in one case four tons of hay per acre. Many of the acid soils were from unused fields and some from geological areas showing much limestone rock. Now lime and limestone are the substances which will correct the acidity so we are, from this test, led to infer that our soils need additions of lime. The action of this substance in the soil is very complex and but imperfectly understood.

Since Nova Scotia has many limestone areas, one might expect the soil to be well provided with lime, but such is not the case; it being a land of hills and valleys, of brooks and rivers, the limestone is carried away especially from the light soils of the limestone areas. From the limestone soils of

England, 1429 pounds per acre to the depth of nine inches were carried away in the drainage water per year, or in the forty years of the experiment, about 28 tons per acre.

Limestone has the following uses in the soil:—

(1) To supply calcium, a necessary element of plant food; 4 tons of clover per crop, for 30 crops would require 3,510 pounds of Calcium.

(2) To neutralize the acids resulting from the decay of organic material or the decomposition of such fertilizers as ammonium sulphate. Very often the soils with the least organic matter show the least lime and vice versa; e. g., a muck soil at Truro shows at the surface:—

	Inorganic matter.	Volatile matter.	Lime
At surface...........	7%	85.90%	3.20%
1st ft. of subsoil......	79%	15.73%	1.40%

(3) To effect a chemical dissolving of potash silicates and to set free phosphoric acid from iron and aluminum phosphates.
(4) For its flocculating effect on the clay soils.

Caustic Lime, CaO, has an antiseptic effect on the soil. Hutchinson of Rothamsted Exp. station, England, in June, 1913, says: "Caustic lime is a valuable antiseptic and when applied to the soil, even in the presence of large quantities of carbonate of lime, disturbs or destroys the state of equilibrium existing between the micro-flora and micro-fauna of the soil; it kills many bacteria and destroys the larger protozoa which exert a depressing effect on bacterial growth; the inhibitory action of caustic lime on soil bacteria persists until all the oxide is changed to the carbonate; this is followed by a period of active bacterial growth.

Organic Matter and Nitrogen.

Table 4 gives averages of the organic matter and nitrogen in the three groups of soil studied: these indicate organic

matter deficient in nitrogen, just as we have in the peat soils much organic matter with little nitrogen; we must say then, that while the organic matter averages fairly well, the nitrogen content is low, there being too much cropping for the amount of nitrogen returned.

Again, these soils are, as a rule, acid; consequently, the bacteria, which break up the organic matter and form nitrates and which cannot work in the presence of acids, are rendered inactive; this brings into question the availability of the nitrogen and suggests the use of a base like lime.

The great problem in Nova Scotia seems to be to increase and maintain the amount of available nitrogen.

The analyses thus far show:—

(1) That our soils have a good supply of potash but that it is only slightly available.

(2) That phosphoric acid in many soils is in small amounts, is about one third available and hence soon used.

(3) That, while volatile matter is quite high, it is deficient in nitrogen.

(4) That lime is *very deficient* in many soils.

Hopkins of Illinois, in speaking of the average soils of the United States says "Phosphorus is the key to permanent agriculture on these lands."

The recommendation from this study is, if the soil is in fair condition, supply (1) limestone in the powdered form, 2 tons per acre every four years; (2) a mineral phosphate as basic slag, or if obtainable, ground rock phosphate, 600 lbs. per acre every three or four years; this will put the land in condition for growing legumes which, if ploughed under or fed and the manure returned to the land, will increase the store of nitrogen and organic matter. This organic matter will help to dissolve the potash which is present, locked up in the soil.

THE PHENOLOGY OF NOVA SCOTIA, 1913—BY A. H. MACKAY, LL.D.

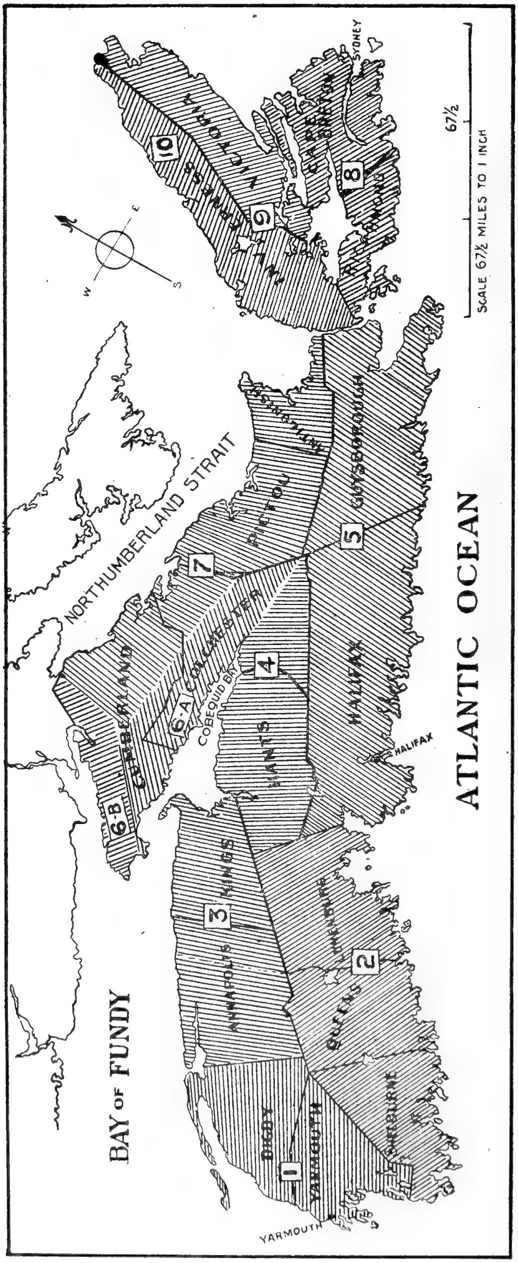
(Read by title 12 May 1914)

These phenological observations were made in the schools of the province of Nova Scotia as a part of the Nature Study work prescribed. The pupils report or bring in the flowering or other specimens to the teachers when they are first observed. The teachers record the first observation and observer, and vouch for the accurate naming of the species. The schedules from 200 of the best schools form the material of the following system of average dates (phenochrons) for the ten biological regions of the Province, and the phenochrons of the Province as a whole. The compilation of the 200 schedules was done by H. R. Shinner, B. A.

The Province is divided into its main climate slopes or regions not always coterminous with the boundaries of counties. Slopes, especially those to the coast, are subdivided into belts, such as (a) the coast belt, (b) the low inland belt, and (c) the high inland belt, as below:—

No.	Regions or Slopes.	Belts.
I.	Yarmouth and Digby Counties,	(a) Coast, (b) Low Inlands, (c) High Inlands.
II.	Shelburne, Queens & Lunenburg Co's.	” ” ”
III.	Annapolis and Kings Couties,	(a) Coast, (b) North Mt., (c) Anapolis Valley, (d) Cornwallis Valley, (e) South Mt.
IV.	Hants and Colchester Counties,	(a) Coast, (b) Low Inlands, (c) High Inlands.
V.	Halifax and Guysboro Counties,	” ” ”
VI.A.	Cobequid Slope (to the south),	“ “ “
VI.B.	Chignecto Slope (to the northwest),	“ “ “
VII.	Northumberland Sts Slope (to the n'h)	“ “ “
VIII.	Richmond & Cape Breton Co's.,	“ “ “
IX.	Bras d'Or Slope (to the southeast),	“ “ “
X.	Inqerness Slope (to Gulf, N. W.),	“ “ “

The ten *regions* are indicated on the outline map on the next page.



THE TEN PHENOLOGICAL REGIONS OF NOVA SCOTIA.

THE PHENOLOGY OF NOVA SCOTIA, 1913.

[Compiled from over 200 local observation schedules.]

Year 1913.

Day of the year corresponding to the last day of each month.

Jan.	31	July	212
Feb.	59	Aug.	243
March	90	Sept.	273
April	120	Oct.	304
May	151	Nov.	334
June	181	Dec.	365

For leap year add one to each except January.

When First Seen. — Observation Regions.

Year 1913.	1. Yarmouth and Digby	2. Shelburne, Queens and Lunenburg	3. Annapolis and Kings	4. Hants and South Colchester	5. Halifax and Guysboro	6. S. Cobequid Slope, (S. Cum. & Col.)	7. N.Cumb, Col,Pictou and Antigonish	8. Richmond and Cape Breton	9. Bras d'Or Slope, Inv. and Victoria	10. Inverness Slope to Gulf	Average Dates
1 Alnus incana, Wild	94	93	101	96	117	100	98	111	110	110	103
2 Populus tremuloides	....	107	98	115	125	112	109	114	123	123	114
3 Epigea repens, L.	85	92	98	104	103	104	217	112	110	110	102
4 Equisetum arvense	115	113	117	121	123	121	119	126	123	123	120
5 Sanguinaria Canadensis	....	130	140	125	....	119	118	132	158	158	135
6 Viola blanda	112	114	117	119	115	117	117	119	119	119	116
7 Viola palmata, *cucullata*	114	118	119	122	123	120	120	126	124	124	121
8 Hepatica triloba, etc	....	116	150	123	125	....	116	134	128	128	127
9 Acer rubrum	117	121	116	121	124	121	118	129	121	121	120
10 Fragaria Virginianum	116	117	121	119	120	119	120	125	121	121	119
11 " fruit ripe	158	158	159	163	163	168	165	172	166	166	163
12 Taraxacum officinale	114	117	121	125	125	125	124	130	127	127	123
13 Erythronium Americanum	118	149	155	124	157	124	123	150	....	....	137
14 Coptis trifolia	118	119	125	128	125	127	128	131	130	130	126
15 Claytonia Caroliniana	....	125	136	124	129	115	121	143	120	120	126
16 Nepeta Glechoma	128	123	160	123	132	139	129	146	126	126	133

When Becoming Common. — Observation Regions.

Year 1913.	Average Dates	1. Yarmouth and Digby	2. Shelburne, Queens and Lunenburg	3. Annapolis and Kings	4. Hants and South Colchester	5. Halifax and Guysboro	6. S. Cobequid Slope, (S.Cum. & Col.)	7. N.Cumb, Col,Pictou and Antigonish	8 Richmond and Cape Breton	9. Bras d'Or Slope, Inv. and Victoria	10. Inverness Slope to Gulf
1 Alnus incana, Wild	111	104	101	113	104	120	109	102	118	120	120
2 Populus tremuloides	123	....	117	107	121	132	....	114	121	136	136
3 Epigea repens, L.	111	102	102	109	112	111	115	115	118	116	116
4 Equisetum arvense	126	121	119	126	128	129	128	125	132	128	128
5 Sanguinaria Canadensis	138	....	130	145	130	....	122	124	135	158	158
6 Viola blanda	123	123	120	123	124	123	123	124	124	126	126
7 Viola palmata, *cucullata*	128	123	123	126	127	130	129	121	132	131	131
8 Hepatica triloba, etc	131	....	116	153	131	133	....	122	138	128	128
9 Acer rubrum	126	122	126	121	128	129	130	124	132	126	126
10 Fragaria Virginianum	128	125	125	129	127	128	131	128	132	130	130
11 " fruit ripe	172	173	170	171	173	175	172	171	175	171	171
12 Taraxacum officinale	130	128	123	127	131	131	133	130	135	134	134
13 Erythronium Americanum	143	135	154	158	131	159	133	128	152	....	....
14 Coptis trifolia	133	130	126	131	134	132	133	136	138	134	134
15 Claytonia Caroliniana	132	....	125	142	131	135	119	126	149	129	129
16 Nepeta Glechoma	141	156	129	163	130	134	145	136	150	131	131

THE PHENOLOGY OF NOVA SCOTIA, 1913.—*Continued.*

Year 1913.

Day of the year corresponding to the last day of each month.

Jan.	31	July	212
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When First Seen. Observation Regions. 1. Yarmouth and Digby	2. Shelburne, Queens and Lunenburg	3. Annapolis and Kings	4. Hants and South Colchester	5. Halifax and Guysboro	6. S. Cobequid Slope, (S.Cum.&Col.)	7. N.Cumb, Col,Pictou and Antigonish	8. Richmond and Cape Breton	9. Bras d'Or Slope,Inv. and Victoria	10. Inverness Slope to Gulf	Average Dates	No.	Year 1913.	When Becoming Common. Average Dates	1. Yarmouth and Digby	2. Shelburne, Queens and Lunenburg	3. Annapolis and Kings	4. Hants and South Colchester	5. Halifax and Guysboro	6. S. Cobequid Slope, (S. Cum & Col.)	7. N.Cumb, Col,Pictou and Antigonish	8. Richmond and Cape Breton	9. Bras d'Or Slope,Inv. and Victoria	10. Inverness Slope to Gulf
127	128	126	131	138	130	123	144	135	135	131	17	Amelanchier Canadensis	138	132	133	134	136	142	137	134	148	143	143
....	204	....	125	166	....	143	....	....	....	159	18	" fruit ripe	168	....	230	....	130	166	....	148	....	....	....
126	137	134	139	140	135	134	152	148	148	139	19	Prunus Pennsylvanica	145	136	142	139	145	145	143	140	158	151	151
....	....	....	....	....	....	....	222	....	....	222	20	" fruit ripe	240	....	....	....	....	....	....	....	240	....	....
123	125	128	136	136	135	134	152	153	153	137	21	Vaccinium Can. and Penn.	145	134	133	136	144	143	144	143	160	159	159
....	174	139	145	....	....	165	227	....	....	170	22	" fruit ripe	180	....	174	167	148	....	....	166	247	....	....
139	140	146	150	152	143	148	156	153	153	148	23	Ranunculus acris	156	151	147	154	158	156	153	157	163	164	164
139	145	145	155	159	152	156	164	158	158	153	24	R. repens	159	148	152	155	161	161	157	164	168	163	163
150	143	137	143	149	138	143	154	158	158	147	25	Trill. erythrocarpum	153	161	147	143	150	158	147	149	156	163	163
131	132	138	144	148	142	146	157	151	151	144	26	Rhododendron Rhodora	149	139	139	145	147	154	149	151	160	154	154
139	145	136	150	151	149	149	151	146	146	146	27	Cornus Canadensis	154	152	152	143	156	156	155	155	165	153	153
....	208	170	149	157	....	....	183	....	....	173	28	" fruit ripe	184	....	225	175	156	161	....	....	207	....	....
141	147	146	146	151	147	145	155	147	147	147	29	Trientalis Americana	152	144	154	155	154	157	154	151	156	149	149
152	150	149	156	157	156	150	156	....	....	153	30	Clintonia borealis	159	157	156	153	163	166	161	157	160	....	....
....	155	168	154	157	....	160	168	....	....	160	31	Calla palustris	165	....	164	170	162	158	....	168	171	....	....
156	152	148	160	162	151	157	170	164	164	158	32	Cypripedium acaule	164	162	159	155	165	165	159	160	174	170	170
156	153	153	158	161	156	159	168	162	162	158	33	Sisyrinchium angustifolium	165	162	159	159	162	166	162	164	171	172	172
159	159	163	167	168	160	160	166	151	151	160	34	Linnæa borealis	164	162	165	164	172	172	162	163	167	157	157
154	148	144	150	154	147	144	160	161	161	152	35	Kalmia glauca	159	160	154	148	155	157	157	154	163	171	171
141	160	157	159	160	152	157	161	169	169	158	36	Kalmia augustifolia	163	150	167	158	162	165	158	163	166	171	171
157	158	154	158	163	157	158	175	160	160	160	37	Cratægus oxyacantha	166	163	165	159	163	166	165	165	176	168	168
157	156	160	158	162	162	155	156	167	167	160	38	Cratægus coccinea, etc.	164	164	162	161	166	170	164	162	162	167	167
161	158	160	165	165	157	166	174	169	169	164	39	Iris versicolor	168	165	165	163	170	171	162	170	176	170	170
157	159	166	164	167	169	166	173	175	175	167	40	Chrysanthemum Leucanthmum	172	166	166	171	170	173	172	170	176	178	178
164	163	154	162	154	....	160	170	160	160	161	41	Nuphar advena	167	172	170	155	168	161	....	170	172	170	170

160	155	152	156	167	154	157	164	160	160	158	42 **Rubus strigosus**	165	171	163	160	161	174	157	163	165	167	167
....	205	176	....	....	....	164	227	160	160	182	43 " fruit ripe	193	....	220	....	....	....	....	170	227	175	175
159	167	168	171	176	172	172	174	....	....	170	44 Rhinanthus Crista-galli	174	168	173	172	172	183	172	175	178	....	....
163	164	164	162	167	156	166	165	156	156	161	45 Rubus villosus	167	168	170	169	171	171	158	171	167	163	163
....	229	....	....	....	....	179	249	165	165	197	46 " fruit ripe	211	....	235	236	....	....	....	180	267	175	175
162	165	166	171	156	....	170	169	....	....	165	47 Sarracenia purpurea	171	168	172	169	185	161	....	172	171	....	....
160	**169**	....	174	167	....	171	171	175	175	170	48 Brunella vulgaris	174	171	172	....	176	167	....	172	175	180	180
171	170	170	180	167	173	164	....	181	181	173	49 Rosa lucida	174	176	171	171	180	167	173	176	176	....	....
163	161	165	169	165	171	170	174	178	178	169	50 Leontodon autumnale	175	172	168	172	173	173	178	176	171	182	182
....	136	....	164	175	....	159	163	177	177	164	51 Linaria vulgaris	168	....	143	....	165	177	....	164	157	185	185
125	127	125	125	132	124	121	136	135	135	128	52 Trees appear green	141	139	139	139	138	146	136	136	153	142	142
142	132	131	137	143	143	135	146	149	149	141	53 Ribes rubrum cultivated	146	139	139	140	143	151	149	140	148	155	155
....	....	....	187	....	....	212	208	....	....	201	54 " fruit ripe	204	....	....	....	193	....	....	212	208	....	....
129	136	138	140	147	143	137	148	155	155	143	55 R. nigrum cultivated	148	139	140	141	146	154	148	142	153	156	156
....	....	....	150	....	....	....	210	....	....	180	56 " fruit ripe	180	....	....	....	150	....	....	....	210	....	....
130	136	131	142	150	150	141	152	155	155	144	57 Prunus Cerasus	150	141	141	137	149	156	156	145	158	159	159
....	218	....	180	....	....	219	....	....	....	206	58 " fruit ripe	206	....	218	....	180	....	....	219	....	....	....
139	131	135	140	153	148	140	155	150	150	144	59 Prunus domestica	150	144	143	142	146	160	155	145	163	155	155
139	142	140	147	159	148	143	161	156	156	149	60 Pyrus Malus	157	149	152	149	154	165	156	150	166	164	164
158	156	153	156	165	158	155	170	166	166	160	61 Syringa vulgaris	166	164	162	160	163	171	162	161	173	171	171
162	156	160	160	161	160	159	170	159	159	169	62 Trifolium repens	165	166	163	162	164	167	166	170	174	173	173
146	149	157	157	160	165	161	170	167	167	160	63 Trifolium pratense	165	157	158	161	162	168	173	169	171	173	173
173	162	158	164	158	164	169	167	....	....	164	64 Phleum pratense	170	173	166	165	171	163	169	176	....	173	173
....	180	164	166	168	....	167	....	190	190	175	65 Solanum tuberosum	177	....	191	164	166	168	....	179	....	190	....
106	107	109	119	114	115	119	114	110	110	112	66 Ploughing (first of season)	123	121	116	119	131	124	123	132	122	123	123
118	117	127	127	125	125	131	126	131	131	126	67 Sowing	134	127	126	134	134	133	138	143	138	137	137
117	114	131	132	123	129	133	119	121	121	124	68 Potato-planting	134	126	124	142	144	132	151	144	121	129	129
123	124	124	130	142	120	130	122	113	113	124	69 Sheep-shearing	133	130	133	135	140	147	133	145	133	121	121
170	173	....	....	167	....	212	216	....	....	187	70 Hay-cutting	198	....	189	....	....	167	....	216	223	....	....
....	251	238	288	238	....	238	256	....	....	251	71 Grain-cutting	264	....	264	....	309	246	....	242	260	....	....
....	261	267	295	275	....	271	273	....	....	274	72 Potato-digging	289	....	274	....	336	281	....	276	282	....	....
59	87	76	75	80	75	75	92	85	85	79	73a Opening of rivers	....	....	....	....	....	....	....	....	....	....	....
74	101	80	89	90	....	98	99	85	85	89	73b Opening of lakes	....	....	....	....	....	....	....	....	....	....	....
107	147	105	112	106	122	121	126	131	131	121	74a Last snow to whiten ground	....	....	....	....	....	....	....	....	....	....	....
125	119	115	129	120	128	131	132	141	141	128	74b " fly in air	....	....	....	....	....	....	....	....	....	....	....
115	129	119	143	138	160	133	143	152	152	138	75a Last spring frost—hard	....	....	....	....	....	....	....	....	....	....	....
151	157	140	157	154	....	160	174	159	159	157	75b " —hoar	....	....	....	....	....	....	....	....	....	....	....
76	107	82	85	164	91	84	131	104	104	102	76a Water in streams—high	....	....	....	....	....	....	....	....	....	....	....
....	269	....	....	....	....	259	....	....	....	264	76b " —low	....	....	....	....	....	....	....	....	....	....	....
....	256	....	287	295	....	240	248	....	....	265	77a First autumn frost—hoar	....	....	....	....	....	....	....	....	....	....	....
....	302	259	....	....	....	279	295	....	....	284	77b " —hard	....	....	....	....	....	....	....	....	....	....	....
333	305	277	304	304	....	303	304	....	....	304	78a First snow to fly in air	....	....	....	....	....	....	....	....	....	....	....
339	320	331	305	306	....	306	305	....	....	316	78b " whiten ground	....	....	....	....	....	....	....	....	....	....	....
....	354	....	....	360	....	....	350	....	....	355	79a Closing of lakes	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	349	....	....	349	....	....	349	79b " rivers	....	....	....	....	....	....	....	....	....	....	....
99	84	85	85	86	74	89	91	89	89	87	81a Wild ducks migrating, N	....	....	....	....	....	....	....	....	....	....	....
265	304	....	....	....	....	....	308	....	....	292	81b " S	....	....	....	....	....	....	....	....	....	....	....
108	82	83	84	78	86	80	88	86	86	86	82a Wild geese migrating N	....	....	....	....	....	....	....	....	....	....	....

THE PHENOLOGY OF NOVA SCOTIA, 1913.—*Continued.*

Year 1913.

Day of the year corresponding to the last day of each month.

Jan.	31	July	212
Feb.	59	Aug.	243
March	90	Sept.	273
April	120	Oct.	304
May	151	Nov.	334
June	181	Dec.	365

For leap year add one to each except January.

When First Seen. Observation Regions. 1. Yarmouth and Digby	2. Shelburne, Queens and Lunenburg	3. Annapolis and Kings	4. Hants and South Colchester	5. Halifax and Guysboro	6. S. Cobequid Slope, (S. Cumb. & Col.)	7. N. Cumb, Col, Pictou and Antigonish	8. Richmond and Cape Breton	9. Bras d'Or Slope, Inv. and Victoria	10. Inverness Slope to Gulf	Average Dates	Year 1913.		When Becoming Common. Average Dates	1. Yarmouth and Digby	2. Shelburne, Queens and Lunenburg	3. Annapolis and Kings	4. Hants and South Colchester	5. Halifax and Guysboro	6. S. Cobequid Slope, (S. Cumb. & Col.)	7. N. Cumb, Col, Pictou and Antigonish	8. Richmond and Cape Breton	9. Bras d'Or Slope, Inv and Victoria	10. Inverness Slope to Gulf
284	349	283	....	....	....	291	298	....	....	301	82b Wild geese migrating	S.	....	....	....	....	....	....	....	....	....	....	....
111	79	79	86	94	106	87	94	99	99	93	83 Melospiza fasciata	North	....	....	....	....	....	....	....	....	....	....	....
70	76	68	79	73	62	79	70	85	85	75	84 Turdus migratorius	"	....	....	....	....	....	....	....	....	....	....	....
79	66	163	75	80	70	92	87	91	91	89	85 Junco hiemalis	"	....	....	....	....	....	....	....	....	....	....	....
121	117	100	131	123	....	124	139	117	117	121	86 Actitis macularia	"	....	....	....	....	....	....	....	....	....	....	....
....	96	87	111	....	....	124	135	170	170	128	87 Sturnella magna	"	....	....	....	....	....	....	....	....	....	....	....
126	121	102	120	121	116	115	119	118	118	117	88 Ceryle Alcyon	"	....	....	....	....	....	....	....	....	....	....	....
118	157	104	130	152	117	134	137	....	....	131	89 Dendrœca coronata	"	....	....	....	....	....	....	....	....	....	....	....
120	140	133	134	151	124	140	148	131	131	135	90 D. æstiva	"	....	....	....	....	....	....	....	....	....	....	....
136	125	100	124	186	126	127	142	139	139	124	91 Zonotrichia alba	"	....	....	....	....	....	....	....	....	....	....	....
160	152	145	143	139	142	141	151	143	143	146	92 Trochilus colubris	"	....	....	....	....	....	....	....	....	....	....	....
110	160	106	131	131	145	141	160	....	....	135	93 Tyrannus Carolinensis	"	....	....	....	....	....	....	....	....	....	....	....
....	144	104	134	140	86	136	125	124	124	124	94 Dolychonyx oryzivorus	"	....	....	....	....	....	....	....	....	....	....	....
94	145	91	138	120	141	144	143	118	118	125	95 Spinis tristis	"	....	....	....	....	....	....	....	....	....	....	....
....	122	90	153	123	....	154	180	114	114	131	96 Setophaga ruticilla	"	....	....	....	....	....	....	....	....	....	....	....
....	150	....	....	146	114	156	....	114	114	132	97 Ampelis cedrorum	"	....	....	....	....	....	....	....	....	....	....	....
113	137	125	123	121	115	138	141	142	142	130	98 Chordeiles Virginianus	"	....	....	....	....	....	....	....	....	....	....	....
89	84	95	96	100	100	96	104	107	107	97	99 First piping of frogs		....	....	....	....	....	....	....	....	....	....	....
80	93	106	108	106	107	109	110	116	116	105	100 First appearance, snakes		....	....	....	....	....	....	....	....	....	....	....

THUNDERSTORMS—PHENOLOGICAL OBSERVATIONS, NOVA SCOTIA, 1913.

The indices indicate the number of stations from which the Thunderstorms were reported on the day of the year specified.

OBSERVATION REGIONS.

1. Yarmouth and Digby.	2. Shelburne, Queens and Lunenburg.	3. Annapolis and Kings.	4. Hants and South Colchester.	5. Halifax and Guysboro.	6. S. Cobequid Slope (S. Cum. and Col.)	7. North Cum., Col., Pictou and Antig.	8. Richmond and Cape Breton.	9. Bras d'Or Slope (Inv. & Victoria).	10. Inverness Slope to Gulf.	Total Year 1913.
						3				3
	7									7
8^{2}	8^{6}	8								8^{9}
			12	12						12^{2}
	13^{2}									13^{2}
					14					14
	18		18	18	18					18^{4}
			19	19						19^{2}
	26		26							26^{2}
	27^{2}						27			27^{3}
31										31
				39						39
				50						50
	53^{2}			53						53^{3}
								63	63	63^{2}
							64			64
	65				65		65^{6}	65	65	65^{10}
	70						70			70^{2}
						73				73
74^{2}	74^{5}		74^{2}							74^{9}
75	75	75^{4}	75			75^{3}	75			75^{11}
				78						78
						84	84^{2}			84^{3}
			87							87
				88						88
						90				90
95	95^{3}			95						95^{5}
				96						96
				102						102
	105									105
						106				106
		107		107^{3}						107^{4}
	108									108
109^{5}	109^{19}	109	109							109^{26}
	110				110					110^{2}
						111				111
115	115		115			115				115^{4}
						116				116
	117^{3}	117^{5}	117^{6}		117^{2}	117^{4}				117^{20}

THUNDERSTORMS—PHENOLOGICAL OBSERVATIONS, NOVA SCOTIA, 1913.

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OBSERVATION REGIONS.

1. Yarmouth and Digby.	2. Shelburne, Queens and Lunenburg.	3. Annapolis and Kings.	4. Hants and South Colchester.	5. Halifax and Guysboro.	6. S. Cobequid Slope (S. Cum. and Col.)	7. North Cum., Col., Pictou and Antig.	8. Richmond and Cape Breton.	9. Bras d'Or Slope (Inv. & Victoria).	10. Inverness slope to Gulf.	Total Year 1913.
......	......	......	118^{12}	118^{5}	118^{6}	118^{4}	......	......	......	118^{27}
......	119	......	......	119	119^{2}	119^{6}	......	......	......	119^{10}
......	......	......	......	......	......	......	......	121	121	121^{2}
127	127	......	127	......	......	......	......	......	......	127^{3}
......	128	......	......	......	......	......	......	......	......	128
......	......	......	......	129	......	......	......	......	......	129
......	......	......	......	......	......	......	133	......	......	133
134	......	......	134^{2}	......	134	......	......	......	......	134^{4}
......	......	......	135^{2}	......	......	135	......	......	......	135^{3}
......	......	......	......	138	......	......	......	......	......	138
......	139	......	139^{12}	139^{4}	......	139^{9}	139	139^{4}	139^{4}	139^{35}
......	......	......	140^{2}	......	......	......	......	140	140	140^{4}
......	......	146	......	......	......	146	......	......	......	146^{2}
......	......	......	......	......	......	147	......	......	......	147
......	......	......	......	......	......	148^{2}	......	......	......	148^{2}
149^{5}	149^{7}	149^{5}	......	......	......	......	......	......	......	149^{17}
153	153^{5}	......	153^{2}	......	......	......	......	153	153	153^{10}
......	......	......	......	......	......	153^{3}	......	......	......	154^{3}
......	155^{10}	155^{3}	155^{3}	155^{5}	......	155	155	......	......	155^{23}
......	......	156	156^{2}	......	......	......	......	......	......	156^{3}
......	157	......	......	......	......	......	......	......	......	157
......	158	158^{2}	158^{2}	......	......	158	......	......	......	158^{6}
......	159	......	159	......	......	159	......	......	......	159^{3}
......	......	......	160	......	......	......	......	......	......	160
......	......	......	......	......	......	......	164	......	......	164
......	......	......	......	......	165^{2}	......	165	......	......	165^{3}
167^{4}	167^{22}	167^{7}	167^{7}	167^{5}	167	167	167	167	167	167^{50}
......	......	......	168	168	......	......	......	......	......	168^{2}
......	169^{5}	......	......	......	......	......	......	......	......	169^{5}
......	170^{10}	170	170^{7}	170^{3}	......	170	......	170^{2}	170^{2}	170^{26}
......	......	......	171	......	......	......	......	......	......	171
......	172	......	......	......	......	......	......	......	......	172
......	173^{2}	......	......	173	......	......	173^{10}	173^{2}	173^{2}	173^{17}
......	......	......	......	......	......	176	......	......	......	176
......	178^{8}	178^{2}	178^{2}	178	178^{2}	178	......	......	......	178^{16}
......	......	......	......	......	......	179	......	......	......	179
......	......	181	......	......	......	......	......	......	......	181
......	......	......	......	......	......	......	185	......	......	185
......	......	......	......	......	......	......	195	......	......	195

THUNDERSTORMS—PHENOLOGICAL OBSERVATIONS, N.S., 1913.—*Continued.*
The indices indicate the number of stations from which the Thunderstorms were reported on the day of the year specified.

OBSERVATION REGIONS.

1. Yarmouth and Digby.	2. Shelburne, Queens and Lunenburg.	3. Annapolis and Kings.	4. Hants and South Colchester.	5. Halifax and Guysboro.	6. S. Cobequid Slope (S. Cum. and Col.)	7. North Cum., Col., Pictou and Antig.	8. Richmond and Cape Breton.	9. Bras d'Or Slope (Inv. & Victoria).	10. Inverness slope to Gulf.	Total Year 1913.
							201			201
							202^{2}			202^{2}
							216			216
							221			221
							222^{2}			222^{2}
	231									231
	239^{2}	239^{2}								239^{4}
	240		240			240^{3}	240			240^{6}
						242				242
	246	246								246^{2}
						247				247
	251^{2}	251								251^{3}
						255	255^{2}			255^{4}
						270				270
			274							274
	275		275	275		275				275^{4}
		276								276
277^{2}	277									277^{3}
		281								281
	286									286
	289^{2}			289		189				289^{4}
						290				290
						294				294
300										300
			301			301				301^{2}
304										304
							308			308
		311								311
	314									314
			315							315
	344									344

APPENDIX III

LIST OF MEMBERS, 1913-14

ORDINARY MEMBERS

Name	*Date of Qdmission*
Bancroft, George R., County Academy, Halifax	Jan. 7, 1908
Barnes, Albert Johnstoue, B. SC., service inspector Maritime Telephone & Telegraph Co., Halifax	May 13, 1912
Bishop, Watson L., Dartmouth, N. S	Jan. 6, 1890
Bowman, Maynard, B. A., Public Analyst, Halifax	Mar. 13, 1884
Bronson, Prof Howard Logan, PH. D., Dalhousie College, Halifax	Mar. 9, 1911
Brown, Richard H., Halifax	Feb. 2, 1903
*Campbell, Donald A., M. D., Halifax	Jan. 31, 1890
Campbell, George Murray, M. D., Halifax	Nov. 10, 1884
Colpitt, Parker R., City Electrician, Halifax	Feb. 2, 1903
Creighton, Prof. Henry Jermain Maude, M. A., M. SC., DR. SC., F. C. S., Swarthmore College, Swarthmore, Penn., U. S. A	Jan. 7, 1908
*Davis, Charles Henry, C. E., New York City, U. S. A	Dec. 5, 1900
Doane, Francis William Whitney, City Engineer, Halifax	Nov. 3, 1886
Donkin, Hiram, M. E., Deputy Com. of Mines, Halifax	Nov. 30, 1892
Fergusson, Donald M., chemist, Acadia Sugar Ref. Co., Halifax	Jan. 5, 1909
*Forbes, John, Halifax	Mar. 14, 1883
*Fraser, C. Frederick, LL. D., Principal School for the Blind, Halifax	Mar. 31, 1890
Freeman, Philip A., Hx. Elect. Tramway Co., Halifax	Nov. 6, 1906
Graham, Prof. Stanley Newlands, B. SC., N. S. Technical College, Halifax	Nov. 28, 1913
Harlow, A. C., Montreal	Jan. 7, 1908
Harris, Prof. David Fraser, M. D., D. SC., F. R. S. E., Dalhousie College, Halifax	Feb. 29, 1912
Hattie, William Harrop, M. D., Supt. N. S. Hospital, Dartmouth	Nov. 12, 1892
Irving, G. W. T., Education Dept., Halifax	Jan. 4, 1892
Johnstone, J. H. L., Demonstrator of Physics, Dalhousie University, Halifax	Dec. 2, 1912
*Laing, Rev. Robert, Halifax	Jan. 11, 1885
McCallum, A. L., B. SC., analyst, Halifax	Jan. 7, 1908
McCarthy, Prof. J. B., B. A., M. SC., King's College, Windsor, N. S	Dec. 4, 1901
McColl, Roderick, C. E., Halifax	Jan. 4, 1892
*MacGregor, Prof. James Gordon, M. A., D. SC., F. R. S., F. R. S. C., Edinburgh University, Edinburgh, Scotland (Died May, 1913)	Jan. 11, 1877
McInnes, Hector, LL. B., Halifax	Nov. 27, 1889
MacIntosh, Donald Sutherland, B. A., M. SC., Dalhousie College, Halifax	Mar. 9, 1911
*McKay, Alexander, M. A., Supervisor of Schools, Halifax	Feb. 5, 1872
*MacKay, Alexander Howard, B. A., B. SC., LL. D., F. R. S. C., Superintendent of Education, Halifax	Oct. 11, 1885
Mackay, Prof. Ebenezer, PH. D., Dalhousie College, Halifax	Nov. 27, 1889
*MacKay, George M. Johnstone, Schenectady, N. Y., U. S. A	Dec. 28, 1903
MacKenzie, Prof. Arthur Stanley, PH. D., F. R. S. C., Dalhousie College, Halifax	Nov. 7, 1905
*McKerron, William, Halifax	Nov. 30, 1891
Moore, Prof. Clarence L., M. A., F. R. S. C., Dalhousie College, Halifax	Jan. 7, 1908
Morton, S. A., M. A., County Academy, Halifax	Jan. 27, 1893
Murray, Prof. Daniel Alexander, PH. D., Montreal	Dec. 18, 1903
Nickerson, Carleton Bell, M. A., Dalhousie College, Halifax	Mar. 9, 1911

*Life Members.

Date of Admission

Piers, Harry, Curator Provincial Museum and Librarian Provincial Science Library, Halifax	Nov. 2, 1888
*Poole, Henry Skeffington, A. M., ASSOC. R. S. M., F. G. S., F. R. S. C., CAN. SOC. C. E., HON. MEM. INST. M. E., Guildford, Surrey, England	Nov. 11, 1872
*Robb, D. W., Amherst, N. S	Mar. 4, 1890
Sexton, Prof. Frederic H., B. SC., Director of Technical Education, Halifax	Dec. 18, 1903
*Smith, Prof. H. W., B. SC., Agricultural College, Truro, N. S.; Assoc. Memb. Jan. 6, 1890	Dec. 1900
*Stewart, John, M. B. C. M., Halifax	Jan. 12, 1885
Winfield, James H., Manager Mar. Tel. & Tel. Co., Halifax	Dec. 18, 1903
*Yorston, W. G., C. E., Assistant Road Commissioner, Halifax	Nov. 12, 1892

ASSOCIATE MEMBERS

Allen, E. Chesley, Yarmouth, N. S	Nov. 28, 1913
*Caie, Robert, Yarmouth, N. S	Jan. 31, 1890
Connolly, Prof. J. C., PH. D., St. Francis Xavier, Antigonish, N. S	Nov. 5, 1911
Haley, Prof. Frank R., Acadia College, Wolfville, N. S	Nov. 5, 1901
Harlow, L. C., B. SC., Prov. Normal School, Truro, N. S	Mar. 23, 1905
Haycock, Prof. Ernest, Acadia College, Wolfville, N. S	May 17, 1899
James, C. C., LL. D., C. M. G., Deputy Min. of Agriculture, Toronto, Ontario	Dec. 3, 1896
Jennison, W. F., Truro, N. S	May 5, 1903
*Johns, Thomas W., Yarmouth, N. S	Nov. 27, 1889
*MacKay, Hector H., M. D., New Glasgow, N. S	Feb. 4, 1902
Payzant, E. N., M. D., Wolfville, N. S	Apr. 8, 1902
Perry, Prof. Horace Greeley, M. A., Acadia University, Wolfville, N. S	May 12, 1913
Pineo, Avard V., LL. B., Kentville, N. S	Nov. 5, 1901
*Reid, A. P., M. D., L. R. C. S., Middleton, Annapolis, N. S	Jan. 31, 1890
*Robinson, C. B., PH. D., New York Botanical Garden, New York, U. S. A. (Died 1913)	Dec. 3, 1902
*Rosborough, Rev. James, Musquodoboit Harbour, N. S	Nov. 29, 1894

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*Life Members.

CORRESPONDING MEMBERS

Date of Admission

Ami, Henry M., D. SC., F. G. S., F. R. S. C., Geological Survey, Ottawa, Ontario. . Jan. 2, 1892
Bailey, Prof. L. W., PH. D., LL. D., F. R. S. C., Fredericton, N. B. . . . . Jan. 6, 1890
Ball, Rev. E. H., Tangier, N. S. . . . . Nov. 29, 1871
Barbour, Capt. J. H., R. A. M. C., F. L. S., Nowgong, Bundelkhand, Central India. . . . . Dec. 28, 1911
Bethune, Rev. Charles J. S., M. A., D. C. L., F. R. S. C., Ontario Agricultural College, Guelph, Ontorio. . . . . Dec. 29, 1868
Cox, Prof. Philip, B. SC., PH. D., Fredericton, N. B. . . . . Dec. 3, 1902
Dobie, W. Henry, M. D., Chester, England. . . . . Dec. 3, 1897
Faribault, E. Rodolphe, B. A., B. SC., Geological Survey of Canada, Ottawa; Assoc. Memb. March 6, 1888. . . . . Dec. 3, 1902
Ganong, Prof. W. F., B. A., PH. D., Smith College, Northampton, Mass. U.S.A. Jan. 6, 1890
Hardy, Maj-General Campbell, R. A., Dover, England. (Sole surviving Foundation Member; originally elected Dec. 26, 1862, and admitted Jan. 26, 1862.). . . . . Oct. 30, 1903
Hay, George U., D. SC., F. R. S. C., St. John, N. B. (Died 1913). . . . . Dec. 3, 1902
Matthew, G. F., M. A., D. SC., LL. D., F. R. S. C., St. John, N. B. . . . . Jan. 6, 1890
Mowbray, Louis L., Hamilton, Bermuda. . . . . May 3, 1907
Peter, Rev. Brother Junian. . . . . Dec. 12, 1898
Prest, Walter Henry, M. E., Bedford, N. S.; Assoc. Memb., Nov. 29, 1894. . . . . Nov. 2, 1900
Prichard, Arthur H. Cooper. Librarian Numismatic Museum, New York, USA. Dec. 4, 1901
Prince, Prof. E. E., Commissioner and General Inspector of Fisheries, Ottawa. Jan. 5, 1897

LIST OF PRESIDENTS

OF THE NOVA SCOTIAN INSTITUTE OF NATURAL SCIENCE, AFTERWARDS THE NOVA SCOTIA INSTITUTE OF SCIENCE, SINCE ITS FOUNDATION ON 31ST DECEMBER, 1862.

	Term of Office.
Hon. Philip Carteret Hill, D. C. L.	31 Dec. 1862 to 26 Oct. 1863
John Matthew Jones, F. L. S., F. R. S. C.	26 Oct. 1863 " 8 Oct. 1873
John Bernard Gilpin, M. A., M. D., M. R. C. S.	8 Oct. 1873 " 9 Oct. 1878
William Gossip	9 Oct. 1878 " 13 Oct. 1880
John Somers, M. D.	13 Oct. 1880 " 26 Oct. 1883
Robert Morrow	26 Oct. 1883 " 21 Oct. 1885
John Somers, M. D.	21 Oct. 1885 " 10 Oct. 1888
Prof. James Gordon MacGregor, M.A., D.SC., F.R.S., F.R.S.C.	10 Oct. 1888 " 9 Nov. 1891
Martin Murphy, C.E., D.SC., O.S.I.	9 Nov. 1891 " 8 Nov. 1893
Prof. George Lawson, PH.D., LL.D., F.I.C., F.R.S.C.	8 Nov. 1893 " 10 Nov. 1895
Edwin Gilpin, Jr., M.A., LL.D., D.SC., F.G.S., F.R.S.C., I.S.O.	18 Nov. 1895 " 8 Nov. 1897
Alexander McKay, M.A.	8 Nov. 1897 " 20 Nov. 1899
Alexander Howard MacKay, B.A., B.SC., LL.D., F.R.S.C.	20 Nov. 1899 " 24 Nov. 1902
Henry Skeffington Poole, M.A., D.SC., A.R.S.M., F.G.S., F.R.S.C.	24 Nov. 1902 " 18 Oct. 1905
Francis William Whitney Doane, C.E.	18 Oct. 1905 " 11 Nov. 1907
Prof. Ebenezer Mackay, PH.D.	11 Nov. 1907 " 12 Dec. 1910
Watson Lenley Bishop	12 Dec. 1910 " 11 Nov. 1912
Donald MacEachern Fergusson, F.C.S.	11 Nov. 1912 " ———

NOTE—Since 1879 the presidents of the Institute have been *ex-officio* Fellows of the Royal Microscopical Society.

The first general meeting of the Nova Scotian Institute of Natural Science was held at Halifax, on 31st December, 1862. On 24th March, 1890, the name of the society was changed to the Nova Scotian Institute of Science, and it was incorporated by an act of the legislature in the same year.

The foundation of the Halifax Mechanics' Institute on 27th December, 1831, and of the Nova Scotian Literary and Scientific Society about 1859 (the latter published its Transactions from 4th January to 3rd December, 1859) had led up to the establishment of the N. S. Institute of Natural Science in December, 1862.

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THE

PROCEEDINGS AND TRANSACTIONS

OF THE

Nova Scotian Institute of Science

HALIFAX, NOVA SCOTIA.

VOLUME XIII

(BEING VOLUME VI OF THE SECOND SERIES)

1910-1914

HALIFAX
PRINTED FOR THE INSTITUTE BY THE ROYAL PRINT AND LITHO, LIMITED
1915

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PROCEEDINGS.

Stewart Wallace

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